EVALUATION OF BIOGAS PRODUCTION FROM COMMON REED WITH/WITHOUT CHEMICAL PRETREATMENT AND ENERGY ANALYSIS

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Abstract - This paper aims to investigate the alkaline pretreatment methods by designing and conducting lab-scale biogas production system, the pretreatment was operated on 3 doses of NaOH such as 0%, 2% and 4% with initial parameters of material for TS, VS, and COD were 48.80 ± 0.25%, 46.20 ± 0.14%, and 85,333 ± 13,597 mg/L, respectively. Meanwhile, VFA and ALK was 2,857.14 ± 485.93 ml/L and 1,683.3 ± 131.23 mg-CaCO3/L. pH, Ash, and Moisture content presented 5.69 ± 0.02, 7.00 ± 0.43%, and 51.20 ± 0.25%, respectively. The fermenter with 2.5 liters of the working volume was used for this research. The fermentation of co-substrate was undergone 45 days of HRT. The results were observed 2% NaOH concentration given the highest yield of approximately 20.000 ml, and maximum methane content reached 70.1%. The utilizationTS, VS, and the COD removal of this work was expressed as 71.8%, 63.9%, and 52%, respectively. Besides, the higher calorific values (HCV) and lower calorific values (LCV) produced from biogas were 27.96 MJ/m^3 and 25.19 MJ/m^3, respectively.

Keyword - Grass, Pretreatment, Heating value, Methane, Biogas Production.

I. INTRODUCTION

In recent year, grass has always been considered one of the most effective alternative sources of energy. There are many feasible energy crops, which suitable for biogas production including: Switchgrass (Panicum virgatum), water hyacinth (Eichhorniacrassipes), Sugarcane (Saccharum officinarum), Sorghum (disambiguation), Napier grass (Pennisetum purpureum), Para grass (Brachiariamutica), etc. as well as tree crops due to high nutrient content such as carbohydrate, protein, and easy to harvest [1]. Besides, the value of each type of grass in the biogas process depends on its potential as a high yield: grass species, plant species, can be readily fermented and the eminence of the biogas produced. Almost any plant can be used for biomass which is attractive as a potential feedstock for the production of commercial methane gas. However, fermentability is influenced by age, variety, environmental conditions, characteristics, temperature, soil fertility levels, and harvest management, handling and storage [2].

Biogas is generated via anaerobic digestion (AD) which undergoes four primarily phases: hydrolysis,acidogenesis, acetogenesis, and methanogenesis [3, 4] Figure.1, by activity of microorganism in the absence of oxygen condition [5], the complex organic matters come to be more simple ingredients and compounds [6]. Hence, form biogas in the final phase. Nevertheless, the biogas produced from digestion is a mixture of various gases comprise of methane (CH_4), carbon dioxide (CO_2), oxygen (O_2), hydrosulfide (H_2S), and others gas trace [7]. In which, methane and carbon dioxide are two components that account for the most significant proportion. Biogas production is considered to have long-term potential because of the feasibility [8]. On the other hand, sources for anaerobic digestion are available natural materials that are low costs, plentiful, and easy to exploit or utilize such as crops, sewage, municipal solid waste, animal residues, industrial residues, etc[9].

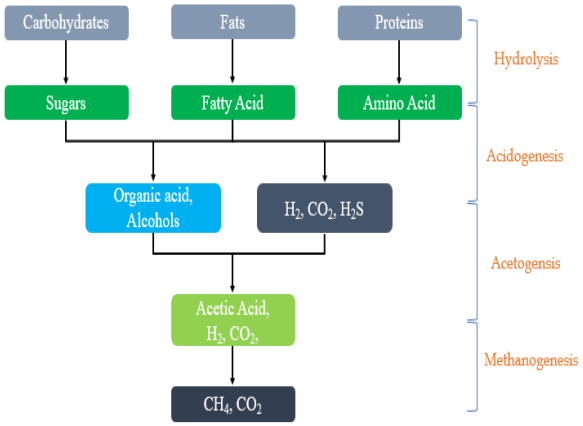


Figure 1: Anaerobic digestion process

Raw materials for biogas are abundant in nature. However, lignocellulosic feedstock is the complex polysaccharide structures arranged by the crosslinking between cellulose, hemicellulose, and lignin [10, 11]. Henceforth, pre-treatment is necessary to break down the existing of those crystalline structures in the material [12], with the purpose to increase the accessibility of enzymes as

well as the ability to decompose thereby improving the gas production process. The selection of method for the materials is significant, depending on the characteristics and attributes of each origin, thereby giving a reasonable method. The properties of lignocellulosic biomass render it resistant to biodegradation. Due to the complexity and variability of biomass chemical structures, the optimal pretreatment method and conditions depend on the types of lignocellulose present. Several structural and compositional properties were found to have impacts on the biodegradability of lignocellulosic biomass, including cellulose crystallinity, accessible surface area, degree of cellulose polymerization, presence of lignin and hemicellulose, and degree of hemicellulose acetylation [5]. The goal of pretreatment is to alter such properties to improve biomass amenity to enzymes and microbes.Chemical pretreatment refers to the use of chemicals, such as acids, bases, and ionic liquids, to alter the physical and chemical characteristics of lignocellulosic biomass [7]. Among the three pretreatment categories discussed, chemical pretreatment has received the most research interest. Although many chemical pretreatment methods have been studied for cellulosic ethanol production, only some of them have been applied to biogas production in AD processes [1]. Thus, this paper aimed to evaluate alkaline concentration for pre-treatment of common reed and investigate the ratio of substrates in fermentation combine with cow dung.

II. MATERIALS AND METHODS

Sample collection: Common reed (Phragmites australis) was gathered from a field in Chiang Mai, Thailand (18°54′48.0″N – 98°59′30.2″E), near Maejo University and Cow dung was gathered from cow's farm at Mae Faek Mai, Chiang Mai province, Thailand (18°58'52.6"N 98°58'26.0"E). After collection, the common reed was shredded by chipping disk machine (multi-purpose shredder model) to get small particle size. For cow dung, the sample was taken under fresh conditions to ensure nutrient richness and exploit the potential of microbial activity. Afterward, all sample was sealed by plastic bags and kept in dry storage until conduct fermentation.



Figure 2: Collection and pretreatment of common reed: (A) Field, (B) Harvesting, (C) Chipping disk machine, (D) Particle size of grass, (E) Pretreatment grass, and (F) After 3 days of pretreatment

Thereafter, materials were transferred to the laboratory for pre-treatment method. Also, specific parameters should be checked by determination through dry material; thus, the grass was undergone solar after seven days then crushed by a blender (Philip HR2116/01 600W).

Chemical pretreatment: pretreatment of common reed was conducted on varying dose sodium hydroxide (NaOH) such as 0%, 2%, and 4% and undergone three days. During three days of the pre-treatment, the materials were well-mixed day by day and checked the variation of pH. Notably, on the second day of pretreatment, the common reed was mixed to reduce particle size then continue one day of process Figure.2. Totally fifteen containers were used for this batch including control test — all samples from pre-treatment stored at the laboratory's temperature. Besides, the pretreated grass also needs for analysis.

Experimental design: the capacity of the fermenter was 3 liters and contained 15% total solids of substrates. The ratio of co-substrate was 1:1 with 3 replications. In other words, the ratio of common reed: cow dung was computed by the mass of total solids. 2.5 liters was working volume of bioreactor Figure.3. All experimental setups were undergone

ambient temperature with the range 26°C–40°C through 45 days of HRT. The capacity of gasholders was 1 liter. The gas produced was measured equivalent to the volume of water decreased from gasholders. Those experiments were run until generating of methane from system discontinue.

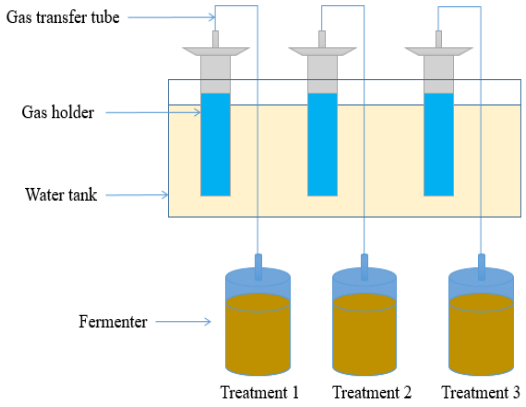


Figure 3: Schematic diagram of this study

Analytical methods: Total solids (TS), volatile solids (VS) were detected according to the standard methods for the examination of water and wastewater[13]. The moisture content was adopted from Vu et al. [14], volatile fatty acids (VFA), alkalinity (ALK) were adopted from Van Tran et al. [15] and chemical oxygen demand (COD) method from Wannapokin et al. [16]. Ash content was measured according to AOAC official method 942.05 [17]. The pH value was observed by pH meter (Oakton PCSTestr 35 waterproof).

Energy analysis: Calorific values were estimated, according to Li et al. [18]. The higher calorific values (HCV) and lower calorific values (LCV)of produced from biogas were determined according to the following formula Eq. 1, 2.

$$HCV_{biogas} = 0.3989 \times MC = 0.0213 \ (R2 = 1) \ldots.Eq.1$$
$$LCV_{biogas} = 0.3593 \times MC = 0.0192 \ (R2 = 1).\ldots Eq.\ 2$$

Where; MC is the methane content in biogas (%).

III. RESULTS AND DISCUSSION

Mono digestion is one of the first preliminary steps of biogas production technology. It has been extensively researched and developed with simply a single substrate involved in fermentation. Besides that, mono digestion laid the foundation for the development of co-digestion. Many investigate on mono-digestion compare with co-digestion to evaluate the influence of the substrate. The mono digestion of a substrate contains high dry matter such as energy crops, plants, etc. the biogas yield based on the volatile solids (organic dry matter) content, which is related to the dry matter ratio in the substrate directly. Common reed (Phragmites australis) is a tall, warm-season, perennial grass. Common reed is widely distributed, ranging all over Europe, Asia, Africa, America, and Australia.

Systematics:

Kingdom: Plantae
Artificial group: Vascular plant
Superphylum: Spermatophyte
Phylum: Magnoliophyta
Class: Liliopsida
Family: Poaceae
Genus: Phragmites
Species: Common reed

The stems are erect, rigid, smooth, hollow, and can grow up to six meters in height. The leaves are stiff, lanceolate and 20-40 cm long and 1-4 cm wide. Flowers occur between July and October and are arranged in tawny spikelets with tufts of silky hair. The silky hairs are purplish and become tawny to dark brown at maturity. The seeds are thin, brown and delicate with a long, narrow bristle [16].

Biogas production from the grass in general and common reed, in particular,containsexcellent potential, and there are limiting research on this material [19]. Although, previously, there were separate discoveries about bioethanol production [20], paper production [21], wastewaters treatment which contains metals [22]. However, studies have not fully exploited their effectiveness. Besides, the value of each type of grass in the biogas process depends on its potential as a high yield: grass species, plant species, can be readily fermented and the quality of the biogas produced. Almost any plant can be used for biomass which is attractive as a potential feedstock for the production of commercial methane gas. However, fermentability isinfluenced by age, variety, environmentalconditions, characteristics, temperature, soil fertility levels, and harvest management, handling and storage [1].

Numerous studies have examined biogas production using grass as a source for renewable energy, it also classified that grasses have the highest methane potential amid potential crops for biogas production. For example, biogas yield from a cultivated variety of canary grass and napier grass was studied previously. The initial characterization of feedstock for TS, VS, and COD was 48.80 ± 0.25%, 46.20 ± 0.14%, and 85,333 ± 13,597 mg/L, respectively. Meanwhile, VFA and ALK was 2,857.14 ± 485.93 ml/L and 1,683.3 ± 131.23 mg-$CaCO^3$/L. pH, Ash, and Moisture content presented 5.69 ± 0.02, 7.00 ± 0.43%, and 51.20 ± 0.25%, respectively.

Lignocellulosic biomass has a complex internal structure. It contains a number of main components main point of using the chemical to remove lignin, hemicellulose, and cellulose, even degradable to microbes and enzymes [23]. Therefore, before taking part in fermentation anaerobic digestion the grass or plant should be suitably conditioned in order to create a suitable environment for the microorganisms, in the

digester a larger target surface area and thus to improve and accelerate the degradation process.

Alkaline pretreatment uses bases, such as NaOH, $Ca(OH)_2$, KOH, and $NH_3.H_2O$. In which, NaOH and KOH are the most effective alkali-treatments for improving the biomass digestibility. To enhance anaerobic bio-gasification of corn stoverthrough wet state NaOH pretreatment [27]. NaOH with 2% concentration and the loading rate of 65 g/L were believed to be optimal in terms of VS loaded and methane production under. The results observed that methane yield wasincreased, and the technical digestion time was shortened by 34.6% for 2% WS NaOH treated stover and showed 88% moisture content, 3-day treatment time and ambient temperature (20°C) were recommended for WS NaOH pretreatment of corn stover. Also by way use alkaline but Jaffar et al. [28] utilized KOH for the wheat straw to improve biogas yield and decrease digestion time, KOH dose in this study are 1%, 3%, 6%, and 9% with a C:N ratio of 25:1. 86% of total solids, 89% of volatile solids and 22% of lignocellulose, cellulose and hemicellulose (22%). Results showed that enhanced biogas production is 45% and cumulative bio-methane yield of 258 $mlCH_4$/g-VS was obtained increased by 41%, compare with pretreated wheat straw digestion also yielded a digestate with higher fertilizer values potassium (138%), calcium (22%) and magnesium (16%). The residual alkali remaining of system can prevent a drop in pH during the acidogenesis step by alkali-pretreated biomass. The effect of alkali pretreatment depends on the lignin content of the biomass [27]. This study results of the experiment were shown in Table 2.

Treatments	HRT (day)	Total biogas (ml)	CH_4
Control 1	45 days	6,290	40.2%
Control 2	45 days	10,157	60.0%
0% NaOH	45 days	11,870	62.3%
2% NaOH	45 days	20,015	70.1%
4% NaOH	45 days	14,900	65.1%

Table 2: Effect of varying pretreatments of NaOH

Solid-state NaOH pretreatment of common reed for three days caused a noticeable change in TS and VS reductions. Moreover, the changes of concentration of NaOH make the chance to increase degradabilityof microorganism by improving accessibility on the surface of the material. Concurrently, several soluble matters such as VFAs and COD which was available from biomass with an increase in NaOH loading at the pretreatment stepdemonstrating that high NaOH loading doesn't give resultsbetter disruption of lignocelluloses. Therefore, the dose of NaOH needs to be controlled and assessed by conducting experimentation. NaOH pretreatment of lignocellulosic biomass could partly dissolve lignin and hemicellulose, in addition to removing cellulose and extracts [11].

Hence, from the results, this study suggested that pretreatment 2% of NaOH is more suitable for common reed to produce high content of methane and yield of biogas. Hydraulic retention time is understood that the average time for a process since the material is involved in the decomposition process until it has done sufficient task. The longer the amount of time material in the digester, the more substrate it breaks down and interacts with the bacteria in the molecule leads to increased methane production. However, The HRT depends on the substrate composition, temperature, as well as the processes. Normally, HRT in mesophilic anaerobic digester conditions is within 15–40 days [29]. Various studies were reported regarding the effect of HRT on biogas yield [30]. The batch experiment was conducted previous by several researcherson soybean residues, papaya peels, sugarcane bagasses, rice straws and greater galangals with the time change from 15 to 35 days, the results observed highest biogas yield at 25th and reduced in the following that days [29, 31]. Total solids and volatile solids are two parameters show degradability efficiency of organic matter in the fermenter, provide information about biogas yield that can be expected and as well as the process efficiency [5].The total biogas yield was reached approximately 20.000 ml, and maximum methane content was 70.1 %.

The highest gas yield produces for 1 day was 880 ml at day 19 of HRT.Therefore, the HRT is directly influenced on anaerobic digestion. The efficiency of this study was expressed by the reduction of TS, VS, and the CODremovalas71.8%,63.9%,and52%, respectively. The results of TS and VS before and after of an anaerobic digestion process represents the degradability efficiency of organic matter in the fermenter.

Wetland plant	HRT	CH_4	Ref
Water lettuce	45 days	62.0 %	Pantawong et al. [23]
Water hyacinth	60 days	66.3 %	Mathew et al. [24]
Napier grass	90 days	63.5 %	Dussadee et al. [25]
Common reed	45 days	70.1 %	This study

Table 3: Comparison of methane content

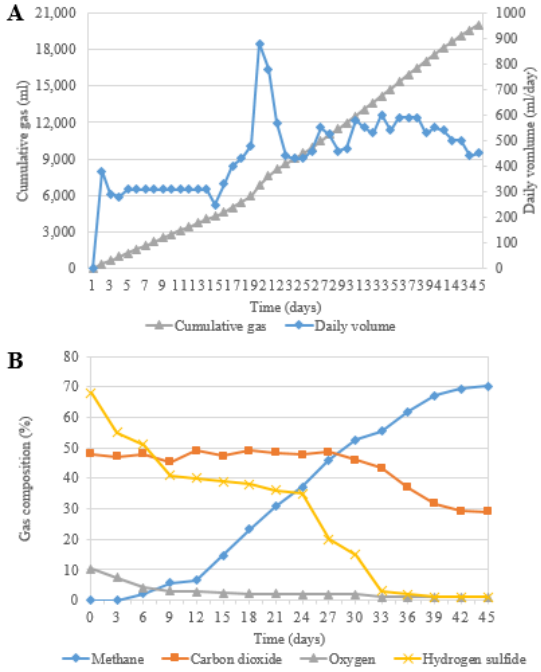


Figure 3: Biogas production of co-digestion: (A) Gas productivity and (B) Gas composition

The pH is a crucial parameter which is related to adaptation time for bacteria in the system. Besides, it shows or represents the smooth operation of the system of a biodigester. The optimum pH levels in anaerobic digestion can be appropriate for methanogenesis ranges from 6.8 to 7.2 [16]. Besides, the variation of VFA and ALK was considered one of the essential factor effects on degradable of bacteria to the fermentation process. The alteration of pH was from 7.14 ± 0.10 to 7.04 ± 0.08. VFAs are one of the indispensable factors in the production of biogas, which are produced by acidogenic and acetogenic bacteria [1,5]. High VFA concentration is the main cause of pH decrease. Decreasing pH can lead to making toxic conditions in the reactor and inhibits the microorganisms. VFA is buffering agents, which is one of the three main essential to maintain the pH value and the ammonia concentration [32]. The drop in pH caused accumulation of VFA. However, ALK prevents the sudden change of pH in the fermenter. A comparison of studies has been implemented to investigate anaerobic digestion of wetland plant were shown in Table 3. Biogas application includes ensuring energy security, decreasing carbon emission, improving economic activity and can be compressed, the same way as natural gas is compressed to CNG, and used to power motor vehicles. The energy analysis was computed by heating value. The results were given for HCV and LCV as 27.96 MJ/m^3 and 25.19 MJ/m^3, respectively. The HHV or gross calorific value is the quotient of the amount of heat that is released when a substance is combusted completely and the mass of the sample. The LHV or net calorific value differs from the HHV of the water that is present in the fuel, and the water that is formed by the combustion of hydrogenated compounds in the fuel is available in the gas phase. That means LHV and HHV are different because the condensation enthalpy is taken into account differently: HHV takes it into account; LHV does not. Therefore, the energy conversion efficiency of the biomethane production via anaerobic digestion integrated with the biogas production process. Consequently, this study experimental result suggested that common reeds biomass with 2 % NaOH pretreatment is suitable for biogas production with achievable of reliable energy efficiency, and it could be applicable for future large-scale biogas production.

IV. CONCLUSION

The common is a suitable feedstock for biogas production. Implemented of biogas lab-scale system gave results significantly for designing and setting up large scale anaerobic digesters. Co-substrate and pretreatment methods also proved improvement the biogas yields. The chemical pretreatment is considered to be one of the most effects for processing of fermentation and required to change the lignocellulose structure of biomass, to increase the accessibility of bacteria so that hydrolysis of material be achieved higher yields. The 2% NaOH is considered to choose for pretreatment. Reducing energy during the run the processis requiredto increase the economy.

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