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Operating condition optimization of water hyacinth and earthworm bedding wastewater for biogas production

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Abstract

Water hyacinth (WH) and nitrogen-rich earthworm bedding wastewater (EW) can be used to enhance biogas production as renewable energy source which would have replaced on the fossil fuels. In this study, an anaerobic digestion was conducted in batch system at laboratory scale in mesophilic condition (28-32 ºC) for 15 days. Response surface methodology (RSM) based on a central composite design was performed for the process optimization to maximize bio-methane potential (BMP). The individual and their interactive effects with three experimental factors in terms of TS of substrate (4-12%), particle size of WH (0.3-1.5 cm) and initial pH (6-8) were evaluated. It was found that the optimum conditions for maximum BMP of 35.50% with the highest specific methane yield of 0.12 $m^3 CH_4/kg\ COD_{removed}$ were found to be 8% TS of substrate, initial pH 7.0 and particle size of WH 0.3 cm. The linear effects of TS of substrate as well as their quadratic effects on BMP were significant ($P<0.05$), while the interactive effects of three parameters were insignificant. The coefficient of determination (R^2) of 96.1% confirms that the model has a good fit with the experimental variables.

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Keywords: Water hyacinth; earthworm bedding wastewater; biogas production; bio-methane potential; response surface methodology.

1. Introduction

Water hyacinth (WH) (*Eichornia crassipes*) is an aquatic plant that can grow very rapidly and free-floating over the water' surface. The invasive potential of this plant has created massive environmental problems in many areas. It has exhibited extremely high growth rates and the coverage of an entire aquatic body by forming thick compact carpet. This thick carpet blocks the passage of sunlight underwater so that the solubility of oxygen in water decrease [1], several problems including destruction of eco-systems, irrigation problems and as a mosquito breeding place leading to increase in mosquito population [2]. Therefore, utilization of WH as a source of biogas for energy to

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replace the fossil fuel will provide an effective management of this plant and at the same time produce a renewable source of energy. Fossil fuel is a finite source of energy and becoming harder to find. WH is easily and abundantly available raw material to produce energy. It is composed of relatively high cellulose, so it has the potential to be used as a source of cellulose for biogas production. In addition, with relatively low lignin content the WH will be more easily digested in the digestion process. Biogas production from organic matter is seeking worldwide attention that is clean in nature, provides a non-polluting and lead to improvement in the environment.

Biogas is a type of biofuel produced from the anaerobic digestion of organic matter from various sources in the biological processes. In this process, organic waste materials are converted into useful biogas [3, 4]. Anaerobic digestion is the consequence of a series in which microorganisms. The composition of biogas varies depending upon the source of its production, approximately 40-75% CH_4, 25-55% CO_2, 0-1% H_2S, 0-3% N_2 and water up to the saturation point [5]. High level of methane can be used as a fuel for cooking, producing vapour, lighting, electricity generation, power for engines, or even powering vehicles or other machines. It has been reported that co-digestion of different materials may enhance the anaerobic digestion process due to better carbon and nutrient balance [6]. The production of methane will be higher when several wastes are combined in a single process and if a single waste only is used, a low methane yield will result due to its low biodegradability or the presence of inhibitory compounds such as potassium and lipids [7]. Digestion of more substrates in the same reactor gives positive effects and the added nutrients could support microbial growth [8]. Generally, lignocellulosic can be used to combine with the liquid manure for co-digestion performing to achieve the goal of increasing methane gas production.

In Thailand, wastewater is released from agricultural production in daily processing operation. Especially, raising earthworms farm is now becoming popular in rural areas. The part of raising earthworms produces the large quantities of nitrogen-rich earthworm bedding wastewater (EW) and releases into the river. Therefore, the utilization of EW to combine with single waste in anaerobic digestion as raw material for co-digestion is to solve the environmental problems and enhances biogas production.

Response surface methodology (RSM) is an aggregation of mathematical and statistical method that are useful for modeling and analysis for designing experiments, evaluating the interactive effects of factors and searching optimal conditions and reducing the number of experiments where a response of interest is influenced by several variables and the objective is to optimize this response [9]. This method is used to evaluate the relationship between response for biogas yield and independent variables, as well as for optimizing the appropriate condition of variables to predict model and to find the best values of responses [10]. Consequently, the design of experiments (DOE) is used to surpass the limitations of traditional experimental methods in terms of time, materials, and the number of experimental trials [11]. In this study, the effects of three experimental factors in terms of TS of substrate, particle size of WH, initial pH and their interactions were investigated by DOE using of RSM technique and try to find the optimum conditions for maximizing bio-methane potential (BMP) in batch reactor in anaerobic digestion.

2. Material and methods

2.1 Substrates

WH was collected from canal in northern Thailand. The stem of the WH was segregated from rest parts and washed two times by water, cut into small pieces (0.3-1.5 cm) and stored in a plastic bag for further use. Composition is mentioned in Table 1. EW sample used in this study was collected from earthworm farm in the northern Thailand that cow manure was used to be source of earthworm bedding. Inoculum was taken from swine local farm located in northern Thailand. Measurements of every item for each sample were repeated for three times and the average value results were presented as mean. Characteristics of the feedstock are also shown in Table 1.

2.2 Batch laboratory anaerobic digestion tests

The batch anaerobic co-digestion test of WH and EW with 20% (v/v) of inoculum was performed with a total capacity of 1L brown glass bottle and a working volume at 700 mL. The substrates were fed in the reactor at different of TS of substrate (4-12%) and different particle size of WH (0.3-1.5 cm) according to the experimental design. 5M NaOH and 5M HCL were used to adjust the pH values (6-8). The reactors were immediately sealed using silicon sealant and parafilm. The water displacement method by using the collecting plastic cylinder was used