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Optimization of Process Parameters for Catalytic Conversion of Solid Bio-waste during Thermophilic Anaerobic Digestion

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Abstract

A comprehensive experimental and modelling study is done on the Biomethanation from water hyacinth plant (Eichhorniacrassipes) to optimise the yield of methane gas with three different catalysts. Water hyacinth grows in the rivers, lakes etc. and it is a huge source of biomass that is easily available. The costs related issues are therefore quite considerable. The experiment of catalytic Biomethanation on water hyacinth was carried out under anaerobic condition in semi-batch digester and batch digester under controlled pH with range of 6.2 to 7.12 and at temperature 30-40^{o}C. In this study, the pH, temperature, VFA (volatile fatty acid) was measured once in every week. This present research incorporates a comparative study on the yield of methane gas between control set-up and catalytic set-up.

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Keywords:Water hyacinth, Different Catalysts, Biomethanation, Anaerobic Condition, Semi-Batch Digester;

1. Introduction

In today's world, rapid urbanization and industrialization of the countries has lead to increased rate of energy consumption. Renewable sources of energy has highly reduced for which there is rise in prices and has become difficult to avail. Biogas, a renewable source of energy, has a promising future and can be used in our long run. New research ideas for biogas production are simply based on Lignocellulosic feedstock. It is considered as an attractive raw material because of its availability in large quantities at low cost not only for the liquid transportation fuel but also for the production of chemicals and materials, i.e. the development of carbohydrate-based biorefineries. Besides

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terrestrial plants, aquatic plants are also a promising renewable energy resource. Water hyacinth, Eichhorniacrassipes is such an aquatic plant. Other examples of lignocellulosic feedstock are straw, rice paddy, sugarcane plants etc. The process of Biomethanation can be expressed in terms of anaerobic digestion is a biological process where organic material is decomposed by anaerobes in absence of air to yield methane rich biogas(Sarkar & Banerjee, 2013). The anaerobic digestion of solid waste leads to high degree of waste stabilization, low production of excess biological sludge, low nutrient(Girisuta, Danon, Manurung, Janssen, & Heeres, 2008) requirement and high production of methane gas as a useful by-product. The concept of biogas production has been applied since past 60 years as a part of domestic sewage treatment(Sarkar & Banerjee, 2013) and traditionally India has been based on dairy manure as feed stock and these Gobar gas plants have been in operation for a long period of time, especially in rural India.

1.1 Biomethanation Process

The whole process of Biomethanation can be divided in four conversion and degradation phases- hydrolysis, acidogenesis, acetogenesis and methanation(Boontian). The Hydrolysis Phase generally includes the hydrolase enzyme secreted by facultative and obligate anaerobes break down cellulose, carbohydrates, protein and fats into monomers. Lignocellulose and lignin degrade slowly and incompletely. The second stage , Acidogenic Phase primary comprise of the monomers produced on hydrolysis are degraded further, by those bacteria, into short-chain organic acids, C1–C5 molecules (e.g., butyric acid, propionic acid, acetate, and acetic acid), alcohols, hydrogen, and carbon dioxide. Intermediate hydrogen affects the fermentation products. Intermediate fermentation products are formed if the partial pressure of hydrogen is high enough(Boontian). The penultimate stage is Acetogenic Phase which generally includes the Acidogenic products of the previous phase serve as substrates for bacteria in the acetogenic phase. Homoacetogenic microorganisms of the acetogenic phase use exergonic H_2 and CO_2 to form acetic acid. Methanogenic bacteria grow concurrently with acetogenic bacteria. Short- chain organic acids and alcohols are converted to acetate. In the conversion of ethanol to acetate, carbon dioxide is used and acetate and hydrogen are produced. Acetate production decreases if hydrogen partial pressure is great enough(Boontian).The last stage is Methanogenic Phase in which the methane production takes place under strict anaerobic conditions. Not all methanogenic bacteria degrade all substrates. It can be divided into acceptable substrates acceptable for methanogenesis into the following three groups:

1) AcetoclasticMethanogenesis: Acetate $\rightarrow CH_4 + CO_2$
2) HydogenotrophicMethanogenesis: $H_2 + CO_2 \rightarrow CH_4$
3) MethyltrophicMethanogenesis: Methanol $\rightarrow CH_4 + H_2O$

1.2 Water Hyacinth and it's characteristics

Water hyacinth (Eichhorniacrassipes) is a monocotyledonous freshwater aquatic plant, belonging to the family Pontederiaceae, related to the lily family (Liliaceae) and is a native of Brazil and Equador region(Kunatsa & Mufundirwa, 2013). It is also a well known ornamental plant found in water gardens and aquariums, bears beautiful blue to lilac colored flowers along with their round to oblong curved leaves and waxy coated petioles. Water hyacinth is considered as a noxious weed in many parts of the world as it grows very fast under favourable conditions. It can achieve a growth rate of 17.5 metric tons per hectare per day(Kunatsa & Mufundirwa, 2013). There is a great discrepancy among policy makers, environmental agencies and research scientists on the way to control this invasive species and the practical benefits that can be obtained. Previous studies depicts that,(Bhattacharya & Kumar, 2010) an ideal bio fuel producing crop must have the following attributes, notably, the naturally grown vegetation, preferably perennials, Rich in cellulose with low lignin content per unit volume of dry matter, easily degradable, should not compete with arable crop plants for space, light and nutrients, resists pests, insects and disease, not prone to genetic pollution by cross breeding with cultivated food crops.Water hyacinth is low in lignin content (10%) and contains high amounts of cellulose (20%) and hemicellulose (33%)(Bhattacharya & Kumar, 2010). In plants, lignin (composed of phenylpropanoid groups) acts as a polymer around the hemicellulose microfibrils, binding the cellulose molecules together and protecting them against chemical degradation. Lignin cannot be converted into sugars. Thus, it is not practical in biofuel production. Their degradation is a high- energy process. Water hyacinth has low lignin, which means the cellulose and hemicellulose are more easily converted to