CHAPTER I
INTRODUCTION

It is a fact that energy is a necessity in daily life. The shortage of energy seems to occur in the near future due to an increasing consumption. Therefore, renewable energy is considered to be an alternative to reduce the demand of fossil fuels. Among alternative fuels, hydrogen is the most interesting one because it is a clean fuel and also gives high-energy yield (based on unit weight). Hence, hydrogen has been suggested as a future fuel (Das, and Veziroglu, 2001). In addition, hydrogen can be used to generate electricity through fuel cells (Lay *et al.*, 1999)

Hydrogen can be produced in several ways: steam reforming of natural gas, thermal cracking of natural gas, and electrolysis of water. All of them require high energy to operate. Moreover, they are not environmentally friendly (Mizuno *et al.*, 2000) and risky in operation. A better way used to produce hydrogen is biological hydrogen production processes because they can be operated under ambient condition. The biological hydrogen production processes can be classified into 2 types: photo and dark fermentations. The dark fermentation is more favorable due to its constant production of hydrogen without light and the process becomes more attractive economically and environmentally if wastewaters are used as raw materials for hydrogen production. Besides hydrogen is a gas generated from dark fermentation, methane is also another gas that can be generated from dark fermentation. According to its compositions, methane has interesting characteristics. Especially, methane has a good calorific value similar to natural gas and propane (www.biogas-renewable-energy.info). One of interesting techniques for biogas production from wastewaters is a use of two-stage processes. The two-stage anaerobic processes can produce a higher methane production rate and yield due to a better balance between the rates of VFA production and consumption as compared to a single process (Parawira *et al.*, 2005).

In this research alcohol wastewater and cassava wastewater were used as a feedstock for hydrogen and methane production. Then two wastewaters have a common problem of a large quantity of cellulosic residues that has to be removed from the wastewater because it upsets the process performance of the anaerobic units, especially upflow anaerobic sludge blanket (UASB) bioreactors. Hence, it has to be separated from both wastewaters, leading to large quantities of residues. As a result, it causes environmental problems, bad smell and water pollution. Because of the low degradation rates of cellulosic materials under anaerobic conditions (Mabee *et al.*, 2011), the improvement of digestibility is of great interest. To enhance the digestibility of fermentation residue, several pretreatment methods are available—physical pretreatment (mechanical disturbance including milling, crushing, or grinding), chemical pretreatment (acid/base hydrolysis or solvent extraction), biological pretreatment (using enzymes or fungi) (Cao *et al.*, 2012), and metal nanoparticle pretreatment (adding silver or nickel nanoparticles) (Zhao *et al.*, 2013 and Mullia *et al.*, 2012). All of these pretreatment methods have the unique purpose of to breaking down the resistance layer of lignin. Lignin is a complex compound with a polymeric structure, resulting in high resistance to biological degradation. Large amounts of lignin have been found to reduce the efficiency of cellulose degradation because lignin serves as a protective barrier to both cellulose and hemicelluloses (Lynd *et al.*, 2002). One of the most innovative methods used to enhance the digestibility of cellulosic residues is to operate anaerobic bioreactors for methane production under severe conditions (50-60 °C and pH 4-5)

The ultimate objectives of this study were to improve the hydrogen production by adding lignocellulosic residue and by a use of two-stage anaerobic process. For the enhancement of hydrogen production from alcohol wastewater by adding lignocelluloseic residue, an anaerobic sequencing batch reactor (ASBR) was firstly operated at different COD loading rates under 55 °C and pH 5.5 to obtain an optimum COD loading rate for the maximum hydrogen production efficiency. After that, the ASBR system was operated at the optimum COD loading rate with different concentrations of adding fermentation residue in order to obtain an optimum fermentation residue concentration for the maximum hydrogen production performance. For the second part of two-stage concept, a cassava wastewater was used instead of alcohol wastewater because the ethanol factory had to stop producing ethanol as a result form the high price of cassava chip. Moreover, the ASBR system was replaced by upflow anaerobic sludge blanket (UASB) unit since UASB is widely used in cassava industry.