Chapter 1

1.0 Introduction

Rising oil prices in the last few years and environmental concerns because of climate change have led to an increasing interest in biofuels. Biofuels are renewable, can substitute fossil fuels, reduce fossil greenhouse gas emissions and they can be produced, where they are needed, to reduce the dependence on oil producing countries. The biofuels that are currently in use, known as first generation biofuels, are mainly produced from sugarcane, maize or soy bean . The mainproducers are Brazil and the USA (Goldschmidt, 2008). Bioethanol, produced from sugarcane and maize, and biodiesel, produced from soybeans, are presently the only biofuels that are produced on an industrial scale. Biofuels are mostly used as fuel additives, because if they are blended with gasoline or diesel in low proportions these mixed fuels can be used in normal cars without major changes of the engine. This is a major advantage of biofuels compared to e.g. hydrogen, because the same distribution system can be used as with normal fuels. In Brazil, however, there exist also cars that can use neat ethanol or so called flex-fuel vehicles that can use both neat ethanol or normal gasoline (Antoni *et al.,* 2007; Walter *et al.,* 2008).

Fermentation is a set of chemical reactions caused by yeast or bacteria to convert simple sugars into ethanol and carbon dioxide. The reaction for the 6-carbon sugar (glucose) to produce ethanol shown in Equation1.0

$$2C_6H_{12}O_6 \xrightarrow[\text{enzyme}]{\text{yeast}} 3CH_3CH_2OH + 2CO_2 \qquad \text{Eq. 1.0}$$

One of the greatest challenges in the 21st century is to take measure to meet the growing demand of energy for transportation, heating and industrial sectors and to provide a raw material for those industries (Hahn-Hagerdal, 2006). Depleting trends of the oil supply has been evidenced by increasing oil prices, which is approached to higher enough than before (Hahn-Hagerdal, 2006).

Key factor to meet all the requirements are a regular supply of clean energy that must be met with a simultaneous substantial reduction of green house gas emissions.

Biofuels can lead to a substantial reduction of greenhouse gas emissions, but they have also been heavily criticized, because first generation biofuels have some severe drawbacks. An increased usage of first generation biofuels leads to an increased need of high-quality agricultural land and fertilizer, which has been associated with global warming and can contaminate groundwater. Biofuel crops are mostly cultivated as monocultures that need more pesticides and reduce biodiversity. Furthermore to make way for these crops, large areas of tropical forests are burned especially in Brazil, what releases CO_2 and leads to erosion of the soils. In Brazil there have also been cases where small farmers have been expelled from their land without compensation, to make place for soybean fields. The most critical point is probably the food vs. fuel problem (Rosillo-Calle *et al.,* 2008). An example is the so called "tortilla-crisis" in the beginning of 2007 in Mexico. Because of the increased demand for maize in the USA due to bioethanol production, the prices for tortillas more than doubled in one week. As 40% of the people have to spend more than 10% of their daily income on tortillas, this was a severe threat to the nourishment of the poor (Goldschmidt, 2007; Searchinger, *et al.,* 2008).

A solution to these problems could be bioethanol that is generated from cellulose, so called second generation biofuel. Bioethanol from cellulose has a much better eco-balance, it does not compete with food production and cellulose is readily available at low costs. Besides the possibility to use waste material or wood, there are also attempts to use feedstock that has not yet been developed such as prairie grass what could further improve availability. The main problem that prevents the widespread use of cellulosic biomass to produce ethanol is the absence of affordable technology to convert it efficiently. This is why researchers tried to develop new technologies such as engineered microorganisms that can convert cellulose to ethanol directly (Laser *et al.,* 2002, Lynd 2005; Hill *et al.,* 2007; De'Amore *et al.,* 1988).

Ethanol has already been producing on a large scale in Brazil, US and some European countries, and it has been recognized as one of the potential renewable biofuelsin the transport sector within next 20 years (Hahn-Hagerdal *et al.* 2006). Ethanol can be blended with petrol or used as neat alcohol in engines without any modification, taking advantage ofthe higher octane number and higher heat of vaporization; furthermore it is an excellent fuel for future advanced flexi-fuel hybrid vehicles (Hahn-Hagerdal et al 2006). Bioethanol is an excellent alternative to fossil fuels, either as a pure fuel withhigh efficiency and performance or as a gasoline additive. Bioethanol is produced by fermentation. Bioethanol can also be produced from a variety of rotten fruits/fruits. Ethanol has several attractive features as an alternative fuel. As a liquid it is easily transported and it also can be blended with gasoline to increase the octane rating of the fuel. The huge fluctuations in the price of petroleum within the past twenty years have made commercial production of fermentation ethanol a more attractive. Because of current interest in the economic conversion of renewable resources into alcohol, residues of a number of crops were evaluated as substrates for alcohol production (Han and Cho, 1973; Bu'Lock, 1979; Jones *et al.,* 1981).

Fruits and fruit wastes are always considered as a potential substrate for bio ethanol production. The present study is encompassing the production of ethanol from rotten fruits including banana, pineapple, mango and rambutan.

Rambutan fruit is widely distributed throughout Indonesia, Malaysia and Southeast Asia. They typically taste sweet though some are sour as well as sweet (Palanisamy *et al,* 2008). It is frequently used for eating and some other useful activities. Mohamed *et al.* (1994) have reported that antimicrobial activity has occurred of some tropical fruit wastes (Guava, starfruit, banana, papaya, Rambutan). Rambutan fruit contains the nutrition value like N, P, K, Ca, Fe, Mg etc. A lot of rotten fruits are making waste and pollute the environments every year, in the tropical countries (Palanisamy, *et al.* 2008).

Bioethanol, produced from sugarcane, pineapple, banana, maize, and biodiesel, produced from soybeans, sunflower, corn oil are presently that are produced on an industrial scale (Hossain et al, 2008 ; Hossain and Fazliny, 2010, Hossain and Boyce, 2009). In Hawaii, Rambutan fruit was harvested producing 120 ton of fruit in 1997. It has been suggested that yields could be increased via improved orchard management, including pollination, and by planting high yielding compact cultivars. This fruit can get damage and hard to store that make a lot of waste every year (Hossain *et al.* 2011).

Banana fruit and its associated residual biomass are amilaceous and lignocellulosic compounds can be used for ethanol production, therefore they must be initially hydrolyzed to be converted into glucose which can be used as a feedstock to produce ethanol by fermentation and distillation. It contains a lot of nutrient elements like .P, K, C, Ca, Me, S, etc. This study is highlighting the impacts of ethanol production from rotten banana fruits. The wooden parts are first hydrolyzed by pretreatment methods to facilitate the availability of sugars for ethanol production (Bohorquez and Herrera, 2005).

In Malaysia, banana is the second most widely cultivated fruit, covering about 26,000 ha with a total production of 530,000 metric tons. About 50% of the banana growing land is cultivated with 'Pisang Berangan' and a lot of banana becomes waste in Malaysia every year (*Hossain et al*, 2011). Banana waste from the facility in Stockholm is used to produce biogas. The gas is now mainly used for vehicle fuel. This process takes place in the Sofielund recycling plant which is a modern facility located outside of the city. Organic waste volumes from bananas in 2007 totaled 10 tons (Granatstein, *et al.* 2008).

The pineapple (Ananascomosus) is the most famous and economically important fruit. In the past, pineapple waste from canneries has been utilized as the substrate for bromelin, vinegar, wine, food/feed yeast and organic acids (Dev& Ingle 1982). Hossain and Fazliny (2010) Stated that good quality of bioethanol could be produced from pineapple. They also reported that viscosity and acid values were maintained under ASTM (American Standard for Testing and Materials) standard. Highest yield of bioethanol was obtained with the solid pineapple waste while lowest bioethanol was obtained from liquid pineapple waste (ChinHo, *et al.* 2000). Mango is the most important fruit crop. It contains good amount of sugar (16-18% w/v) and many numbers of organic acids and also a good antioxidant, carotene (as Vitamin A, 4,800 IU). Some of the varieties are very rich in sugar. Sucrose, glucose and fructose are the principal carbohydrates in ripe mango with small amount of cellulose, hemicelluloses and pectin. The green tender fruits are rich in starch, during ripening the starch which is present is hydrolyzed into reducing sugars (Sastiri, 1962). The unripe fruit contains citric acid, malic acid, oxalic acid and succinic and other organic acids. In ripen fruits the main acid source is malic acid (Bulen *et al.,* 1952). World production for 2001 was estimated as 23 million tones. Every year mango fruit becomes a lot of waste due to the orchard mismanagement and storage after harvest (Wikipedia, 2009b). Bioethanol can be produced from mango fruit juice by fermentation (Reddy *et al.,* 2007). According to the report the mango juice contained 18-20% Total Soluble Solids (TSS) and 5-18.5% of reducing sugars.

1.2 Objectives of the study:

With a view to obtain detailed understanding about the bio-ethanol production from different rotten tropical fruits, the studies were conducted with the following aims:

a. To observe the conversion of biomass to sugar and subsequent conversion of the biomass-sugar to bioethanol.
b. To determine the Bioethanol yield and evaluate the emission analysis.
c. To evaluate the proper enzymes and process optimization.

1.3 The scope of the study:

This research spans on the bioethanol production from different rotten fruits biomasses. It observed the conversion of the biomass to sugar and subsequent conversion of the sugar to bioethanol via yeast fermentation and enzymatic catalysis.