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BIO-HYDROGEN FROM LOW TEMPERATURE THERMO-CHEMICAL CONVERSION OF OIL PALM EFB

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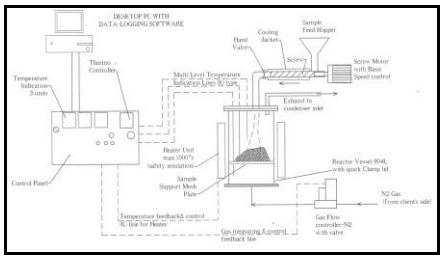
Graphical abstract



Abstract

A low temperature thermo-chemical conversion of biomass to maximise the hydrogen-rich sync gas product to replicate a one-step hydrogen production using oil palm empty fruit bunches (EFB) as an alternative process for renewable hydrogen production is studied. The slow pyrolysis with inexpensive and abundant selected catalysts alkali metal hydroxides such as NaOH is conducted in a pyrolyser unit with a continuous feeding system. The bio-hydrogen is expected to be free of CO and CO2, and the process could be optimized at relatively low temperature of 500-600K, which is significantly lower than the normal temperature ranges for biomass gasification process.

Keywords: Bio-hydrogen, thermo-chemical process, oil palm EFB

1.0 INTRODUCTION

In view of growing environmental concerns and the depletion of the fossil fuel sources, hydrogen is expected to be one of the most prominent alternative energy resources for the near future. Due to the advancement in fuel cell technology, the need for a more sustainable and economical source for hydrogen is crucial. The production of hydrogen from renewable sources offers the possibility of production capacity with lower greenhouse gas emission. Biomass which is abundant and renewable has been considered as one of the most probable source for hydrogen. The production of hydrogen from biomass resources can be said to be carbon neutral as the CO2 released when the biomass is consumed is absorbed by the growing plant through photosynthesis.

A large amount of biomass from the agricultural-based industries by-products is generated each year in Malaysia across a variety of commercial crops. The palm oil sector alone produced approximately 83 million tonnes in 2012 and is expected to increase to 100 million tonnes in 2020[1]. Empty fruit bunches (EFB), one of the main the oil palm processing wastes, has presented itself as a suitable feedstock for bio-fuel productions due to its abundance and favourable physicochemical characteristics [2]. With around 43 million tonnes of EFB produced in 2013, utilization of this readily available feedstock into various uses is greatly observed by those interested in turning biomass into value-added products. There is a continuously increasing interest in the utilization of these biomass as a source of cleaner energy, in line with the Malaysian Renewable Energy Policy and Action Plan 2010 and the Nation's plan of reducing the current carbon emission by 40% by 2020[3].

Table 1 shows the physical and chemical and properties of EFB. With this in mind, the aim for this experiment is to discover an alternative process for producing hydrogen from biomass; in this case empty fruit bunches, via a thermo-chemical process.

Table 1 Properties of EFB Fibres [4]

Properties	Values
Moisture (%)	2.40 - 14.28
Proximate analysis (%)[a]	
Volatile matter	70.03 - 83.86
Fixed carbon	8.97 - 18.30
Ash	1.30 - 13.65
Ultimate analysis (%)[b]	
C	43.80 - 54.76
H	4.37 - 7.42
O[c]	38.29 - 47.76
N	0.25 - 1.21
S	0.035 - 1.10
Chemical composition (%)[a]	
Cellulose	23.7 - 65.0
Hemicellulose	20.58 - 33.52
Lignin	14.1 - 30.45
Extractive	3.21 - 3.7

[a]Weight percent on a dry basis.
[b] Weight percent on a dry and ash-free basis.
[c]By difference.

The main routes for biomass conversion to hydrogen are either through biochemical, biological or thermo-chemical processes. Gasification, as one of thermal routes which provides a competitive way to convert diverse, highly distributed and low-value lingo-cellulosic biomass to a uniform hydrogen-rich syn-gas mixtures [5]. Gasification is normally conducted at a high temperature ranging 700 – 900 oC. A lower temperature thermal catalytic conversion of biomass is an attractive alternative route for producing relatively pure hydrogen. However, more fundamental researches are needed on how to enhance hydrogen fraction yield which include reactor performance studies and catalyst selection and utilization.

Ishida *et al.* [6] proposed a method for the synthesis of hydrogen without CO or CO2 through the reactions of cellulose, alkali metal hydroxides and water vapour at relatively low temperatures (473-623K) at atmospheric pressure. The main reaction for this process is expressed as:

$$C_6H_{12}O_6 \text{ (cellulose)} + 12NaOH + H_2O \rightarrow 6Na_2CO_3 + 12H_2$$

In their work, mixtures of cellulose and sodium hydroxide is injected with water vapour and heated linearly. The product will be sodium carbonate and hydrogen gas. By using this method, hydrogen is formed at a relatively low temperature and little CH4 is produced as a by-product, but most importantly is CO and CO2 was not formed at all. When a Ni catalyst was added to the reacting biomass, production of CH4 was not observed and the hydrogen yield was almost 100%.

Since biomass is composed mainly of cellulose and hemicelluloses, high concentration of hydrogen could be generated from the thermal catalytic treatment of biomass at lower temperature range than those of normal gasification techniques.

2.0 EXPERIMENTAL

The experiment is conducted in a RDF-Pyrolysis system with reactor of internal volume of 904L fitted with external heaters with maximum temperature of 1000 °C. The reactor has the capability for both continuous feeding and batch feeding. The injection points for steam and catalyst could be easily added to the main reactor with minimum modification. Figure 1 shows the schematic diagram of the pyrolyser. The gas from the reactor is passed through a gas cleaning system prior to the gas fraction verification by gas analysers.

The feedstock is pelletized EFB from palm oil processing by-product, as shown in Figure 2. The work by Ishida [6] is based on a much specific materials (cellulose, glucose, etc.). This experiment proposed that it could present itself as a viable method for hydrogen production using a much more complex biomass. This work focuses on the significance of the effect of various process parameters as a function of temperature on both catalytic and non-catalytic performance with reference to the gas yields, gas compositions and hydrogen production rate in both batch feed and continuous feeding mode. The experiment runs initially based on batch feeding and later are repeated using continuous feeding system of up to a rate 500g/ hour. Some of the parameters

are initially set as a constant; moisture content, particle size, and feeding rate.

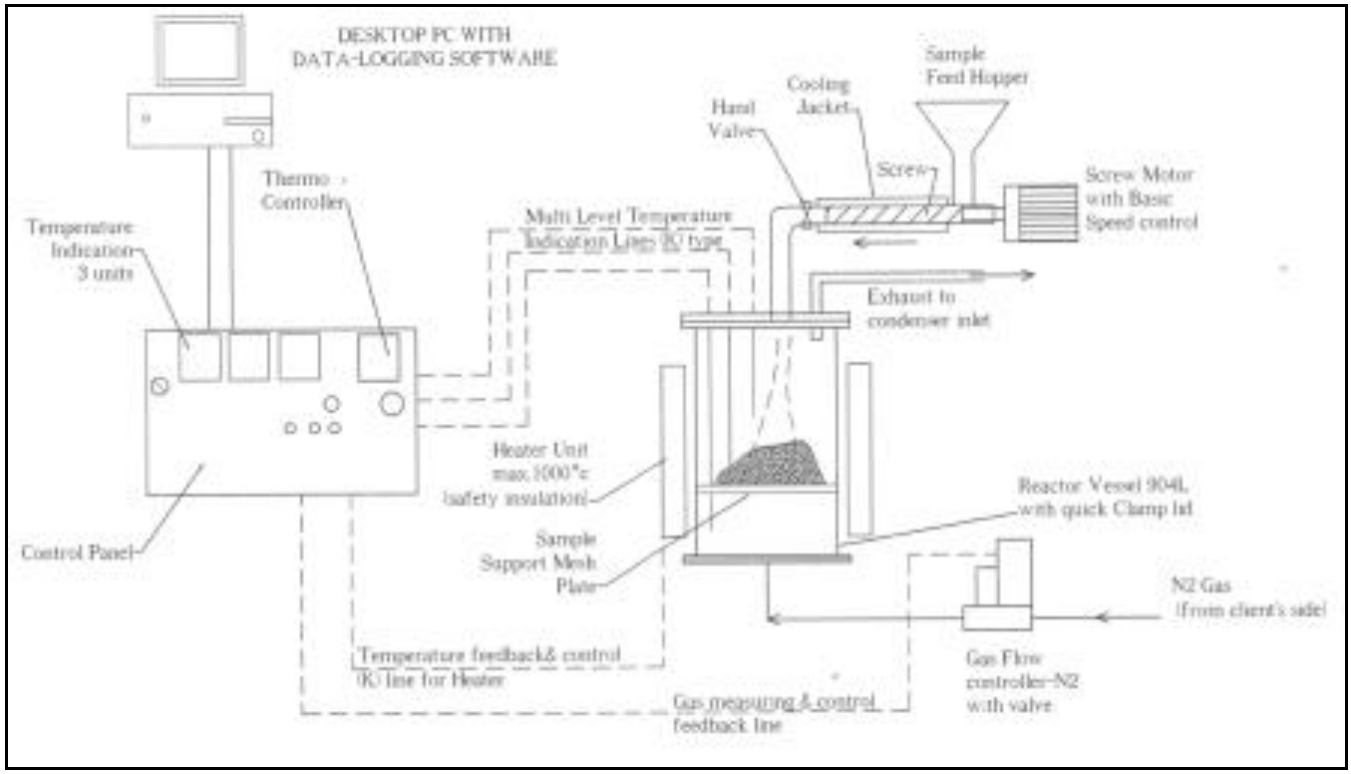


Figure 1 Schematic diagram of the main reactor

Empty Fruit Bunches (EFB)	*EFB Fiber*	*Pelletized EFB*

Figure 2 Empty Fruit Bunch (EFB) Pellets

Since hydrogen element (H) content in biomass (CxHyOz) is comparatively low, the yield of hydrogen gas (H2) from the biomass thermal conversion such as gasification is relatively low (Approx. 6% H2 vs. 25% CH4) [6]. Several types of catalyst that have been identified could play important role in enhancing the proportion of hydrogen fraction from the process will be evaluate in the study. The use of dolomite as a catalyst in biomass gasification had also attracted much attention, because it is inexpensive and abundant and could significantly reduce the tar content of the product gas from a gasifier. Later, the alkali metal hydroxide such KOH is introduced as it is anticipated to give higher yield for hydrogen production compared to NaOH and LiOH [7].

3.0 RESULTS AND DISCUSSION

In Ishida [6] with cellulose as feedstock, the formation of hydrogen started peaking at 500K. However, the formation of methane starts at a temperature above

623K and it was concluded that pure hydrogen without CO, CO2 and CH4 could be obtained at <600K . Therefore, a desirable temperature range for reaction would be at 500K – 600K. Since this experiment is using biomass as feedstock, a broader range of temperature has been selected at 400K – 650K. The experiment runs would narrow down the temperature range and will select the most optimum temperature for the highest fraction of hydrogen production. For primary screening phases, Minitab-17 is used, Setting temperature and feedstock to alkali metal hydroxide ratio as the variable, 8 samples were tested and from the initial results a cause-effect graph are plotted to determine which variable would give significant effect to the result of the experiment.

Early results indicate that the hydrogen yield could be maximised at a narrower temperature range of 500-600K as compare to those obtain from cellulose. However, more fundamental studies are needed on how to enhance hydrogen fraction yield which include reactor performance studies and catalyst selection and utilization.

4.0 CONCLUSION

This low temperature catalytic thermo-chemical conversion study is an alternative way for hydrogen production from biomass. The process could be optimized at relatively low temperatures of 500-600K, which is significantly lower than the normal temperature ranges for biomass gasification. It is anticipated that thermo-chemical route of bio-hydrogen production route is able to progress as competitive method to other commercially available systems in the very near future.

Acknowledgement

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