Experimental Results of Conversion of Oil Palm Trunks and Cocoa Wood to Glucose

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ABSTRACT

Large quantities of lignocellulosic biowastes are produced by oil palm and cocoa plantations every year. As such a project was initiated to study the feasibility of converting oil palm trunks (OPT) and cocoa wood into glucose which can then be used to produce ethanol, a liquid fuel. The project is divided into three parts. In the first part, the OPT were hydrolyzed using different concentrations of sulphuric acid. Maximum glucose yield was found at a hydrolyzing acid concentration of about 1.7%. By using this optimum acid concentration, the second part of this project investigated the distribution of potential glucose yield as a function of position along the OPT. It was found that glucose yield was higher in the outer sections and lower in the inner sections. However, differences in glucose yield along the axis of the trunk are not pronounced except maybe towards the very top part of the trunk. The average glucose yield of OPT was found to be about 25%, based on oven dried weight. The potential of converting cocoa wood into glucose was also studied. The cocoa wood was hydrolyzed using different concentrations of sulphuric acid, and the optimum glucose yield was also found at an acid concentration of around 1.7%.

1. INTRODUCTION

Oil palm is undoubtedly a superior crop as it can be used for a variety of purposes. Its oil is widely used for cooking, baking and the manufacture of toiletry products. Where energy is concerned, the oil palm can be considered as a good source of energy. Its above-ground biomass gives an energy potential of 88.7 boe (barrels of oil equivalent) per ha per year [1]. This is much higher than other plant species such as poplars, willows and Miscanthus that are currently being field tested as potential energy crops in Europe. Willows cultivated in Sweden for instance has a potential of roughly 38.3 boe per ha per year [1].

The oil palm is the most important crop in Malaysia as the country produced 51% of the world production of palm oil in 1994 [1]. It has been estimated that in 1996, Malaysia had about 2.57 million ha (of a total land area of 33 million ha) planted with oil palms. As a result of declining yields, replanting of palm trees is usually carried out after about 25 to 30 years.

Lim [2] estimated that the replanting of 1 ha of palms generates about 80.4 tons of dry biomass, of which palm trunks contribute about 66 tons and fronds contribute 14.4 tons. Replanting activity is expected to increase substantially starting from this decade. Thus large quantities of biomass, of the order of a few million tons of dry matter, will from now on be generated annually [3].

Due to the presence of a high moisture content, which was determined to be around 70% to 80% of original weight, freshly felled trunks cannot be easily burnt in the field. Moreover, leaving the trunks in the field without further processing will physically hinder the process of replanting as palm trunks normally take about five to six years to decompose [4]. In order to increase the rate of decomposition and to avoid attracting insects and diseases, it is now a popular practice to poison the trunks before they are felled.

Although some work on the possible utilization of the biowastes generated as a source of energy had been initiated, research in this area is still limited. Lim and Lim [5], for example, reported on a study where oil palm trunks were carbonized. They found that the charcoal produced was of poor quality in that the calorific value was low while the ash content was high. As mentioned, since oil palm trunks are still rather moist at the time of felling, it was deemed appropriate to initiate a project on the possible conversion, via acid hydrolysis, of these trunks into glucose which could then be used for the production of ethanol as a liquid fuel. As the palm trunk is not completely uniform in structure, this project therefore also investigates the variation, if any, of glucose yield as a function of location on the palm trunk.

Although cocoa cultivation has not progressed as previously anticipated, due to several unfavorable factors, one of which is declining monetary returns, the amount of biomass produced by the industry is still substantial. This is because pruning has to be done to keep mature trees at a height of about 3 m to 4 m so as to enable easy access for spraying and fruit harvesting. Lim [2] reported that pruning generates about 25.2 tons of dry organic matter per ha per year. Since cocoa trees have also been shown to be a good trapper of solar energy and in view of the large amount of lignocellulose biomass produced the authors have also initiated a study in converting cocoa wood into glucose using sulphuric acid hydrolysis.

2. METHODS

For the first set of experiments, sections of oil-palm trunks were procured from a plantation not far from the campus. The sections were identified according to their location along the trunk and were left to dry naturally in the laboratory. Samples that were to be used were washed, left to dry in the laboratory and then ground to about 0.2 mm in size. The experiments were done on samples that came from a location of the trunk that is near to its base and at the periphery. The prepared sample was then subjected to acid hydrolysis as follows.

A small quantity (0.25 g to 2.00 g) was first pretreated with a solution of 75% sulphuric acid for 1 h at 50°C. The ratio of acid to sample weight used was 15:1 (w/w) as this ratio was found to work well on fibers of the oil-palm fruit, baggase and rice husks [6]. Distilled water was then added to the pretreated material to a required concentration of dilute acid (varying from 0.5% to 6.0%). For each acid concentration, the sample was refluxed for 4 h in the dilute solution of boiling sulphuric acid. At least five experimental runs were carried out for each acid concentration.

After the refluxing procedure, the hydrolyzed sample was allowed to cool and later filtered using a piece of Whatman filter paper No. 1. The solution with solids filtered out was neutralized with a 2.5M sodium hydroxide solution. The amount of glucose present in the neutralized solution was then determined enzymatically (glucose enzymatique PAP 1200, Bio Merieux, France). A spectrophotometer (Shimadzu UV-1201) calibrated at 505 nm was used. Standard procedures were followed. In this study, glucose yield was expressed as weight of glucose produced over original weight of sample used.

For the second set of experiments, two whole and freshly cut oil palm trunks of about 25 years old were taken from an oil palm estate in Simpang Ampat, Seberang Prai Selatan, for the study. Both of these trees were about 11.9 m tall, with diameters of about 0.69 m, 0.42 m and 0.38 m at the butt, middle and top parts, respectively.

The trunks were sectioned into lengths of about 0.61 m each and the sections were labelled accordingly. Samples from the outer, middle and inner regions of selected sections of the trunk were taken, cut into smaller pieces and labelled. The samples were then oven-dried, and ground to about 0.2 mm in size. The ground samples were then kept in air-tight plastic bags and labelled. All these prepared samples were then subjected to acid hydrolysis at an acid concentration of 1.7%, as results from the first set of experiments where different acid concentrations were used, indicated that maximum glucose yield was found at a hydrolyzing acid concentration of about 1.7%. The glucose concentration in the hydrolysate was tested using the same method as mentioned earlier.

For the third set of experiments, cocoa wood was used. The cocoa wood was obtained from Chersonese Estate in Kuala Kurau. It was left to dry naturally in the laboratory and was ground to a size of about 0.2 mm. The sample was then subjected to acid hydrolysis using different concentrations of acid. Procedures as in the first set of experiments were followed.

3. RESULTS AND DISCUSSION

The results of the first set of experiments are exhibited in Fig. 1, which shows the percentages by weight of the sample of the oil palm trunk that had been converted to glucose as a function of the concentration of sulphuric acid used for hydrolysis. The data showed that at both low and high acid concentrations, the yield of glucose was lower. The yield was found to be rather sensitive to acid concentration for the acid concentration range of 1% to 2.5%, with a peak in glucose yield at an acid concentration of about 1.7%, thus indicating that 1.7% of acid concentration suffices for optimizing glucose yield. The data also indicated that glucose yield began to decline at acid concentrations higher than about 3%. This decline in yield with increasing acid concentrations may be attributed to a degradation of glucose molecules.

The results in Fig. 1 also indicate that the maximum glucose yield obtained was about 31%. Ismail and Hoi [7], reported that oil palm trunks consist of 34.0% cellulose and 35.8% hemicellulose. Since the hexosans of cellulose and hemicellulose can be hydrolyzed to glucose while the pentosans of hemicellulose are converted to xylose [8], hence, a theoretical glucose yield of about 34.0% to 79.8% should be obtainable from oil palm trunks. If this is the case, then the methods used in this study may have to be modified to increase the glucose yield. On the other hand, Mohamad, et al. [4] reported that preliminary studies indicated that 45.7% of the oil palm trunk are of holocellulose, thus indicating that the maximum glucose yield will be about 45% of the sample dry weight. If this is the case instead, the results in Fig.1 thus indicate that the procedures adopted in this study appear to be quite efficient in converting holocellulose into glucose.

The results of the second set of experiments are shown in Fig. 2 and Fig. 3. The curves in both of the figures show similar behavior in that for both palm trunks, it was found that glucose yield was higher for samples obtained from the outer sections of the trunk and lower for the samples from the inner sections. This observation may be attributed to the structure of the oil palm trunk. Basically, oil palm trunks consist of vascular bundles embedded in ground parenchymatous cells. Lim and Khoo [9] reported that the ground parenchymatous cells consist mainly of thin-walled spherical cells, except in the area around the vascular bundles. Lim and Khoo [9] also reported that each vascular bundle is made up of a fibrous sheath of phloem cells, xylem and parenchyma cells, and that the number of vascular bundles present per unit area decreases from the outer region towards the inner region. The results from the second set of the experiments appear to indicate that hydrolyzing vascular bundles will give a higher glucose yield compared to hydrolyzing parenchyma cells as there are more vascular bundles in the outer sections of the trunk and more parenchyma cells in the inner sections of the trunk. For confirmation, a separate set of experiments was carried out, whereby the vascular bundles and the parenchyma cells were hydrolyzed separately. The results for this separate study are shown in Fig.4, where each data point is the average of five observations. Except for data obtained at the top of the palm trunk, it was found that for most of the studied samples, vascular bundles did give higher glucose yields when compared to parenchyma cells. Therefore the higher glucose yield in the outer region of the trunk compared to the inner region can be attributed to the higher density of vascular bundles found there.

Figure 2 and Fig. 3, also indicate that differences of glucose yield along the axis of the trunk were not pronounced except maybe towards the very top of the trunk. This observation can again be explained by the data in Fig. 4 where for the upper parts of the trunk the differences in glucose yield between parenchyma and vascular bundles are now less pronounced. The decrease in glucose yield of

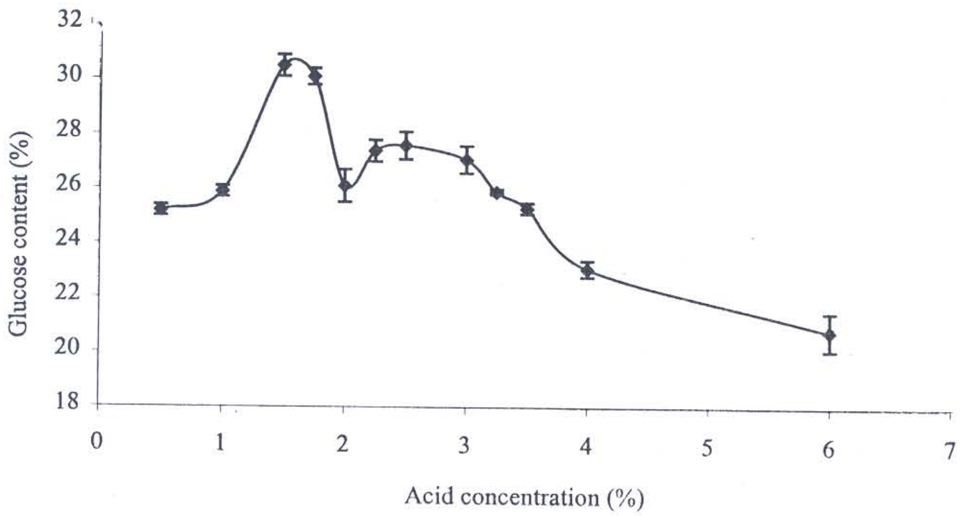

Fig. 1. Glucose content vs. hydrolyzing acid concentration for oil palm trunk.

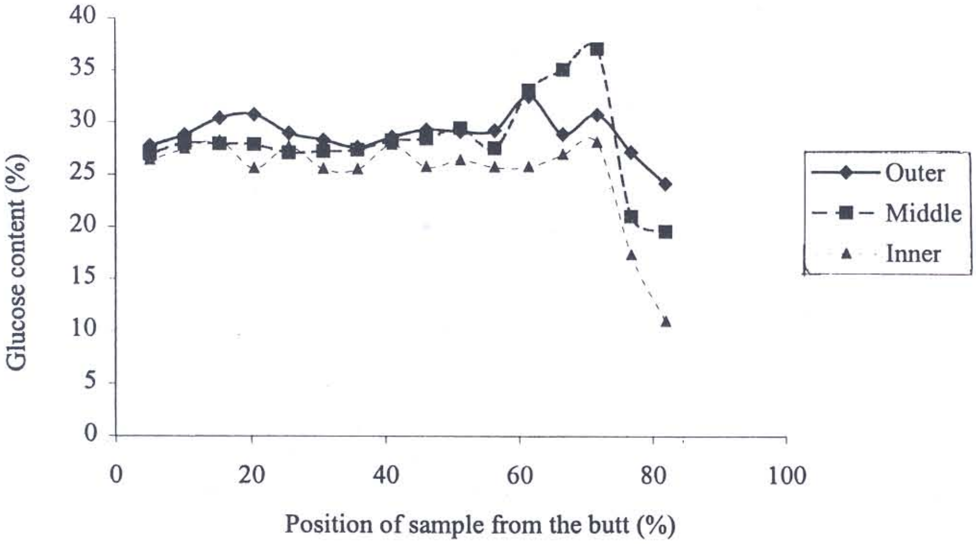

Fig. 2. Glucose content after hydrolysis of oil palm trunk 1.

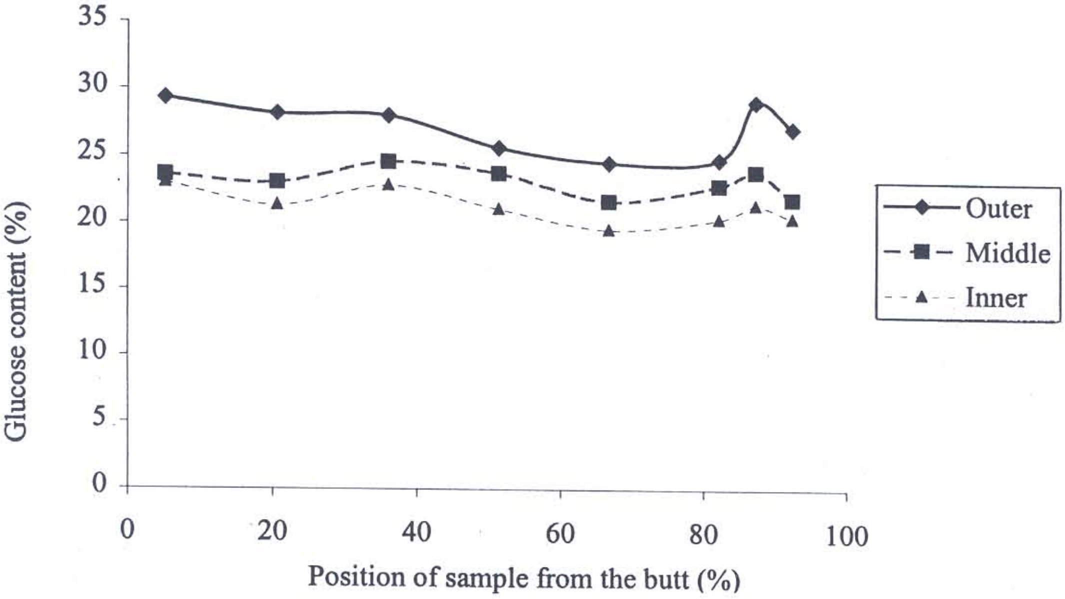

Fig. 3. Glucose content after acid hydrolysis of oil palm trunk 2.

vascular bundles found in this part of the trunk will therefore result in a lowering of overall glucose yield towards the very top portion of the trunk.

The results of the third set of experiments when cocoa wood was hydrolyzed are shown in Fig. 5. It was found that the yield of glucose also varied with the concentration of the hydrolyzing acid used and that the maximum yield also occured at an acid concentration of about 1.7%, similar to the results obtained for oil palm trunks. The maximum glucose yield found here was about 41% compared to about 31% for the palm trunks. This therefore indicates that cocoa wood may be a better feedstock compared to oil palm trunks for the production of ethanol from local biomass.

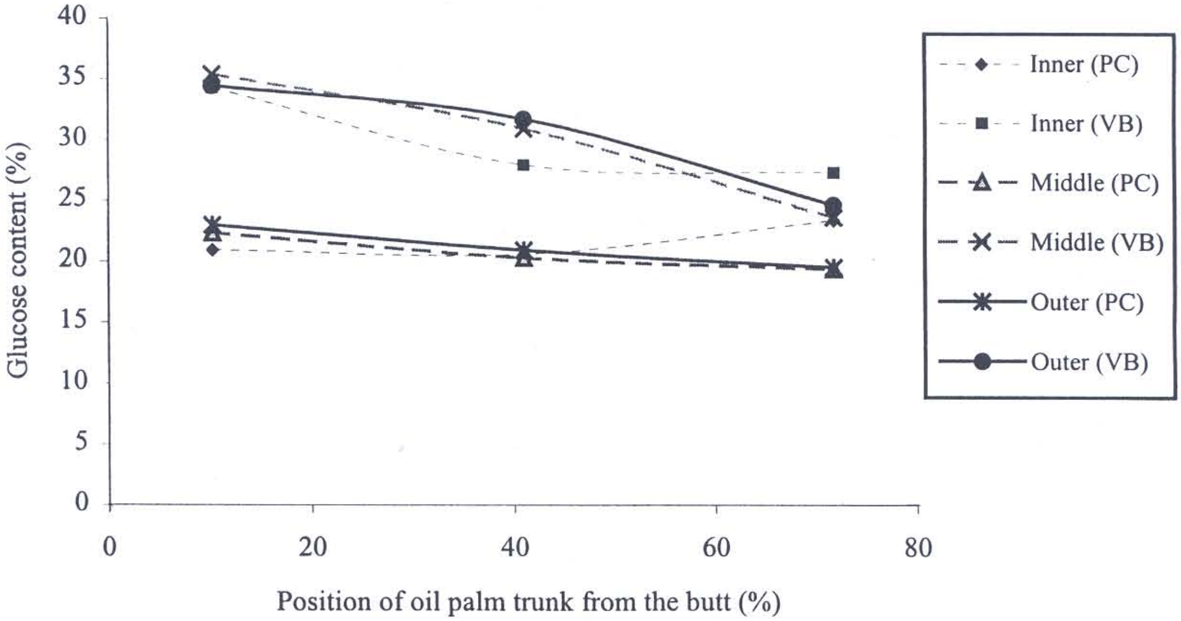

Fig. 4. Glucose content vs. oil palm trunk position for separated parenchyma (PC) and vascular bundles (VB).

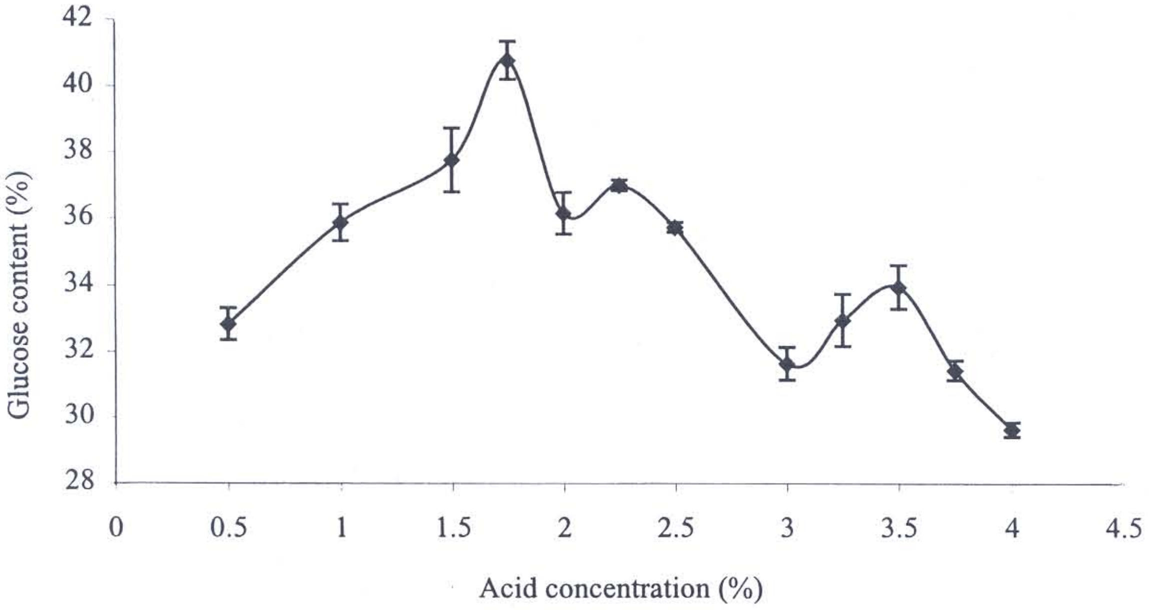

Fig. 5. Glucose content vs. hydrolyzing acid concentration for cocoa wood.

4. ACKNOWLEDGEMENT

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5. REFERENCES

1. Lim, K.O. 1998. Oil palm plantations - a plausible renewable source of energy. *RERIC International Energy Journal* 20 (2): 107-116.

2. Lim, K.O. 1986. The energy potential and current utilisation of agriculture and logging wastes in Malaysia. *Renewable Energy* 8: 57-75.

3. Lim, K.O. 1986. The future energy potential of replanting wastes in Malaysia. *Renewable Energy* 8: 76-85.

4. Mohamad b. Husin; Abd. Halim b. Hj. Hassan; and Ahmad Tarmizi b. Mohammed. 1986. Availability and potential utilisation of oil palm trunks and fronds up to the year 2000. *PORIM Occasional Paper* 20: 1-17.

5. Lim, K.O. and Lim, K.S. 1992. Carbonisation of oil palm trunks at moderate temperatures. *Bioresource Technology* 40: 215-219.

6. Liew, S.S. 1989. Hidrolisis asid bagas dan 'palm press fibre' kepada gula yang boleh difermentasikan. Final Year Dissertation, Food Technology, School of Industrial Technology, Universiti Sains Malaysia.

7. Ismail Abd. Rahman and Hoi, W.K. 1991. Animal feed. In *Oil Palm Stem Utilisation: Review of Research*. Khozirah Shaari; K.C. Khoo; and Abdul Razak Mohd. Ali (eds.), pp: 67-73. Kuala Lumpur: Forest Research Institute Malaysia.

8. Mednick, R.L.; Weiss, L.H.; and Xippolitos, E.G. 1982. Ethanol from cellulosics. *CEP* August: 68-73.

9. Lim, S.C. and Khoo, K.C. 1986. Characteristics of oil palm trunk and its potential utilisation. *The Malaysia Forester* 49(1): 3-22.