

# PRODUCTION OF XYLOSE FROM OIL PALM TRUNK

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A thesis submitted in fulfilment of  
the requirements for the award of the degree of  
Bachelor of Chemical Engineering

Faculty of Chemical & Natural Resources Engineering  
UNIVERSITI MALAYSIA PAHANG

FEBRUARY 2013

## **PRODUCTION OF XYLOSE FROM OIL PALM TRUNK**

### **ABSTRACT**

Oil palm trunk is an oil palm biomass which is the renewable source for the production of many useful products, such as xylose. The study provides efficient analysis on optimizing xylose concentration, in order to obtain higher productivity and yield of xylitol. Xylose is safe, healthy, toxin free substance that can allow people to enjoy the flavor of sugar without negative effects on the body. The objectives of this study are to produce valuable products (xylose and xylitol) from waste oil palm trunk, to identify the effects of sulfuric acid concentration and hydrolysis time on the production of xylose from oil palm trunk. The hydrolysis of oil palm trunk powder was carried out by contacting powder with 3%, 5% and 7% sulfuric acid at 60 °C for 60, 120 and 180 minutes. The acid hydrolysis is using sulfuric acid wood mass ratio of 8: 1 g/g. After hydrolysis reaction, solid part was removed by filtration and the filtrate was neutralized with CaCO<sub>3</sub> and then undergoes detoxification process by using activated carbon powdered with the mass ratio 10:1 of hydrolysate/charcoal powder. The percentage of xylose will be analyzed from the hydrolysate by using High Performance Liquid Chromatography machine. From the literature, the results obtained was the higher acid concentrations led to higher sugar recovery but longer hydrolysis's time caused lower amount in sugar recovery. For a conclusion, the high value products which are xylose can be produce from waste oil palm biomass.

## **PENGHASILAN XYLOSE DARI BATANG KELAPA SAWIT**

### **ABSTRAK**

Batang kelapa adalah biomass kelapa sawit merupakan sumber boleh diperbaharui bagi pengeluaran banyak produk yang berguna, seperti xylose. Kajian ini menyediakan analisis yang berkesan dalam mengoptimumkan kepekatan xylose, untuk mendapatkan produktiviti yang lebih tinggi dan hasil Xylitol. Xylose adalah selamat, menyihatkan, bahan bebas toksin yang membenarkan orang ramai untuk menikmati rasa gula tanpa kesan negatif pada badan. Objektif kajian ini adalah untuk menghasilkan produk berharga (xylose dan Xylitol) dari sisa batang kelapa sawit, untuk mengenal pasti kesan-kesan kepekatan asid sulfurik dan masa hidrolisis pada pengeluaran xylose daripada batang kelapa sawit. Hidrolisis serbuk batang kelapa sawit telah dijalankan dengan merendamkan serbuk dengan 3%, 5% dan 7% asid sulfurik pada suhu 60 ° C selama 60, 120 dan 180 minit. Hidrolisis asid menggunakan asid sulfurik kayu nisbah jisim 8: 1 g / g. Selepas tindak balas hidrolisis, sebahagian pepejal telah ditapis dan turasannya telah dineutralkan dengan CaCO<sub>3</sub> dan seterusnya menjalani proses detoksifikasi dengan menggunakan serbuk arang dengan nisbah jisim 10:1 hidrolisat/arang. Peratusan xylose akan dianalisis dari Hidrolisat dengan menggunakan Kromatografi Cecair Prestasi Tinggi mesin. Daripada literatur, keputusan yang diperolehi adalah kepekatan asid yang tinggi membawa kepada penghasilan gula yang lebih tinggi tetapi masa hidrolisis lagi ini disebabkan jumlah yang lebih rendah dalam penghasilan gula. Kesimpulannya, produk bernilai tinggi seperti xylose boleh dihasilkan daripada sisa biomass kelapa sawit.

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## LIST OF SYMBOLS

$\%$	Percent
$g$	Gramme
$g^{-1}$	Reciprocal gramme
$^{\circ}C$	Degree celcius
$ml$	milliliter
$nm$	nanometer

## LIST OF ABBREVIATIONS

HPLC	High Performance Liquid Chromatography
FTIR	Fourier Transform Infrared Spectroscopy
OPT	Oil Palm Trunk
EFB	Empty Fruit Bunch
OPF	Oil Palm Frond
Wt	Weight
IR	Infrared
UV	Ultraviolet
pH	Potential hydrogen
RPM	Rotation per minutes

## CHAPTER 1

### INTRODUCTION

#### 1.1 Background of Proposed Study

Malaysia produced an estimated 80 million tonnes/year dry weight of oil palm biomass, reflecting the importance and significant potential of biomass. This biomass includes empty fruit bunches, mesocarp fibres, oil palm shells, oil palm fronds and oil palm trunks. Much of the 70 million tonnes/year of oil palm trunk in 4.7million acre plantation produced is burnt or left to rot. Usually the trunks generated from replanting which causes some environment problems. There are reports on application of the oil palm trunk especially for veneer and plywood production being reported (Hamid *et al.*, 2008). The content of  $\alpha$ -cellulose in this waste of oil palm trunk is slightly lower (41%) than wood (45–50%). However, it can play an important complementary role given the possibility of obtaining cellulosic pulp with an  $\alpha$ -cellulose content, and therefore has possible applications in producing paper or pasteboard with different characteristics, especially in areas with

limited forest resources. Some attempts to characterize the palm trunk fibre as a raw material for paper making have been reported. Khoo et al., reported that oil palm trunk fibre gave sulphate pulp with moderate yield and strength. The unbleached pulps would be suitable for medium grade wrapping paper.

A part from that, controlled hydrolysis of cellulose and hemicellulose from oil palm wood allows producing several useful chemical products such as xylose, furfural, glucose and starch enhancing its economic feasibility (Chin *et al.*, 2010). This study actually is to produce xylose and xylitol from oil palm trunk. Xylose is the main building block for hemicellulose, which comprises about 30% of plant matter. Xylose is otherwise pervasive, being found in the embryos of most edible plants. It was first isolated from wood by Koch in 1881.

Bioconversion of lignocellulose to ethanol or xylitol requires the hydrolysis of carbohydrate polymers to their corresponding monomeric sugars prior to fermentation. Lignocellulose hydrolysis has been achieved either by acid hydrolysis or enzymatic hydrolysis. However, acid hydrolysis is the most commonly applied and the method can be used either as a pretreatment preceding the enzymatic hydrolysis or as a method of hydrolyzing lignocellulose for the sugars. As a consequence, the amount of sugars recovered from the raw material is dependent on the reaction time, temperature and acid concentration. However, acid concentration is the most important parameter affecting sugar yield. Apart from that, the sugar obtained from hemicellulose, other by-products, such as furfural, are also produced during the hydrolysis process.

Xylose is a great alternative to white sugar and has none of the negative side effects of sugar. Xylose is a natural sugar that is found in some woody materials besides palm oil biomass like empty fruit bunch and oil palm trunk it also found in straw, pecan shells, cottonseed hulls and corncobs. It is extracted through a scientific process. Xylose is not metabolized by humans. It is completely absorbed and secreted from the kidneys. In animal medicine, xylose is used to test for malabsorption by administration in water to the patient after fasting. If xylose is detected in blood and/or urine within the next few hours, it has been absorbed by the intestines. Reduction of xylose by catalytic hydrogenation produces the non-cariogenic sugar substitute xylitol.

## **1.2 Problem Statement**

Replanting will cause environmental problems. After approximately 25 years of its economic life span, oil palm trunks are cut down so as to allow replanting, the trunks simply being left on the plantation and not been used productively. During replanting, a very large amount of waste trunks are exhausted and cut into pieces and burned simply to prevent the breeding of harmful insects but will cause local environmental pollution.

On the other hand, the demand and attraction for alternatively material from renewable resource had incredibly increased tremendously. Basically, the oil palm trunks contain lignin, holocellulose and quite significant amount of starch. This research is going to solve the problem of getting the best process for the production of cellulose, hemicelluloses and lignin from oil palm trunk. The production of xylose from oil palm trunk is an alternative to white sugar and as sugar-free sweetener. The high value economic conversion of oil palm wood to chemical products is the production of sugars-free sweetener.



### **1.3 Objectives**

The purposes of this research are:

- i. To produce a valuable products (xylose) from waste oil palm trunk
- ii. To study the effect of sulfuric acid ( $\text{H}_2\text{SO}_4$ ) concentration of the acid hydrolysis process.
- iii. To study the hydrolysis time on the production of xylose from oil palm trunk (OPT).

### **1.4 Scopes of Research Work**

- i. The reaction hydrolysis time is selected at 60 to 180 min.
- ii. The concentration of sulfuric acid ( $\text{H}_2\text{SO}_4$ ) is used in range 3 to 7%.
- iii. Acid hydrolysis temperature is constant at  $60^\circ\text{C}$ .
- iv. The percentage of hemicellulose and cellulose need to be measured in the oil palm trunk.
- v. The percentage of xylose compound need to be detected in hemicellulose fraction.
- vi. The raw material used is oil palm trunk (OPT) powder.
- vii. The chemicals used are sulfuric acid ( $\text{H}_2\text{SO}_4$ ), calcium carbonate ( $\text{CaCO}_3$ ), activated charcoal and acetonitrile HPLC grade.
- viii. The equipments used are oven, orbital shaker, high performance liquid chromatography (HPLC) and analytical balance.

## **1.5 Rationale & Significance of study**

- i.** Oil palm trunk seems to be a bio resource which can be entirely converted into valuable chemicals and products. (waste to wealth)
- ii.** The increasing interest on use of oil palm trunk for bioconversion to chemicals is justifiable as these materials are low cost, renewable and widespread sources of sugar-free sweetener.
- iii.** Xylose is a safe, healthy, toxin free substance that can allow people to enjoy the flavor of sugar without negative effects on the body.
- iv.** Xylose causes the growth of positive elements in the intestines. Through this, more absorption of all nutrients can take place. More absorption of nutrients equals a better overall immune system.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Oil Palm Biomass**

The success of palm oil industry in Malaysia is from the confluence of government and private sector strategies and policies. In spite of the huge production, the oil consists of only about 10% of the total biomass produced in the plantation. The remainder consists of huge amount of oil palm wastes such as oil palm trunk and oil palm fronds from the field during replanting, palm shells, mesocarp fibers and empty fruit bunch which is from the mills.

Oil palm tree normally passed their economic age, on an average after 25 years, and due to replanting, the bole length of felled palm trunk is in the range 7m to 13m, with a diameter of 45cm to 65cm, measured at breast height. About 53.87% (dry weight) of fiber bundles can be extracted from a trunk, with the remaining parts are the bark and parenchyma tissues which contribute to 14.45% and 31.68% of the dry weight of the trunk respectively.

Oil palm biomass contains quite significant amount of organic nutrient, which contributes to its fertilizer values. Basically, the oil palm biomass contains about 18 – 21% of lignin, and 65-80% of holocellulose (a-cellulose and hemicellulose), which are more or less comparable with that of other wood or lignocellulosic materials shown in TABLE 1. This makes the oil palm biomass is also suitable as a raw material for the production of pulp and paper, composites, carbon products and chemicals extraction. Oil Palm Trunk (OPT) is a bioresource because it can entirely converted into valuable chemicals and products. The most economic conversion of OPT to chemical product is production of sugars (Rahman *et al.*, 2006; Kasugiet *al.*, 2010). According to Chin *et al.*, 2010, controlled hydrolysis of cellulose and hemicellulose from OPT allows producing several useful chemical products such as xylose furfural, glucose and starch.

Table2.1: Proximate analysis of biomass of oil palm biomass (% , dry weight)

	Oil palm trunk	Oil palm fronds	Empty fruit bunch
lignin	18.1	18.3	21.2
Hemicellulose	25.3	33.9	24.0
a-cellulose	45.9	46.6	41.0
Holocellulose	76.3	80.5	65.5
Ash	1.1	2.5	3.5
Alcohol-benzene solubility	1.8	5.0	4.1

## 2.2 Natural Occurrence of Xylose

Xylose is a sugar isolated from wood and it contains five carbon atoms and includes an aldehyde functional group and that is why it is classified as a monosaccharide of aldopentose type. Apart from that, it is a precursor to hemicellulose, one of the main constituents of biomass. Like most sugars, it can adopt several structures depending on conditions. With its free carbonyl group, it is a reducing sugar. According to Silva et al., xylose is the major component of the hemicellulosic fraction from vegetable biomass, is a pentose sugar that can be converted by biotechnological methods into several chemical products of high value. Same with Abd Rahman et al., 2004, approximately 24% of xylan which is a polymer made of pentose sugar xylose is recovered from the lignocellulosic waste from oil palm empty fruit bunch fiber. The conversion of xylan polymer into monomeric sugar xylose is by reduction of xylan with the presence of catalyst by hydrolyzing acid such as sulfuric acid, hydrochloric acid or hydrofluoric acid.

The natural occurrence of xylose, it is the main building block for hemicellulose, which comprises about 30% of plant matter. Xylose is otherwise pervasive, being found in the embryos of most edible plants. It was first isolated from wood by Koch in 1881. Xylose is also the first saccharide added to the serine or threonine in the proteoglycan type O-glycosylation, and, so, it is the first saccharide in biosynthetic pathways of most anionic polysaccharides such as heparan sulfate and chondroitin sulfate. Dominguez et al., 1997 ; Silva et al., 1998 ; Roberto et al., 2008 said that, the xylose recovered from lignocellulosic waste is by using the acid hydrolysis process. While, according to Kumoro et al., 2008 the lignocellulosic hydrolysis has been achieved by enzymatic hydrolysis. The most commonly method applied is acid hydrolysis and the method can be used either as a pretreatment preceding the enzymatic hydrolysis or as a method of hydrolysing lignocellulose for the sugars. As a consequence, the amount of sugars recovered from the raw material is dependent on the reaction time, temperature and acid concentration (Taherzadeh and Karimi, 2007). However, Roberto et al., 2003 mentioned that the acid concentration is the most important parameter affecting sugar yield.

Xylose is the carbon source for the growth of microorganism for the production of xylitol according to Mohamad et al., 2011. Similarly with Humairah et al., 2004, said the starting material for xylitol production is xylose. During hydrolysis process other sugars such as arabinose, galactose, glucose and some unwanted components such as acetic acid and furfural are also released. For optimum production production of xylitol it is necessary that byproducts like acetic acid and

furfural concentrations in the hydrolysate are to be kept minimum for efficient bioconversion of xylose to xylitol.

Xylose is safe for use in foods. It is antibacterial and antifungal and contains natural healing agents. For this reason, it's become popular in many arenas. Xylose is a great alternative to white sugar and has none of the negative side effects of sugar. Xylose is a natural sugar that is found in some woody materials such as straw, pecan shells, cottonseed hulls, and corncobs. It is also found in berries, spinach, broccoli, and pears. It is extracted through a scientific process. In addition to this, your body actually produces a small amount of Xylose on its own.

### **2.3 Preparation for Samples and Extraction Method for Xylose**

According to Wong *et al.* (2011), the 20-year old palm trunks were debarked chopped into chips size (20x20x20 mm<sup>3</sup>) and grinded into powder which was sieve to obtained size of 20, 40, and 60 mesh and oven-dried at 103°C to 5% moisture content prior to futher work-up. Chemical composition of oil palm wood was determined by using TAPPI standards which are T222-74 for lignin TS os-73 for extractives, and T203 os-61 for cellulose while for hollocellulose was determined using procedure proposed by Wise and Addieco (1946). Wong *et al.* (2011), have used steeping method in order to extract the starch and sugars. They are using two steeping methods with or without 0.5% lactic acid for extracting starch. In the first method, 3.0 g of powdered palm wood which are 20, 40, and 60 mesh size were soaked with 0.2% sodium metabisulphite (Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub>) solution at room temperature

26±2°C for 24, 36, 48 or 60 h. Whereas, for the second method, powdered palm were soaked into 0.2% sodium metabisulphite (Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub>) and 0.5% of lactic acid solutions in ratio 1:5 w/w. Then, the samples were steeped at room temperature 26±2°C for 24, 36, 48 or 60 h. After that, the steeping medium was then filtered off and the residue was washed with 150mL of distilled water. At last, starch content in the filtrate was determined by VIS spectrophotometry by using iodine solution as indicator at wavelength of 650nm (Humphreys and Kelly, 1961).

Astimaret *al.* (2002) stated that, for the samples preparation, the samples was washed with water at first and dried in an oven at 50°C - 60°C until the weight is constant before grinding in a shredder and sifting into fractions of <0.3mm, 0.3 – 0.4mm, and 0.4mm. They have prepared three types of particles, the first is untreated samples which the samples were used as ground and sieve. The second is holocellulose, this was the residual comprising only hemicellulose and cellulose after the lignin was removed by bleaching using Wise and Daddieco (1946). After that, the third sample is an alkali-treated samples which were prepared from all different-sized of samples. One portion in grams of samples was mixed with 20 portions in mL of 1% (w/v) NaOH and heated in a boiling water bath for 2hr. Then, the treated samples was then sieved out and pressed. The samples were oven dried at 50°C - 60°C until its achieved constant weight.

A part from that, similarly with Wong *et al.* (2011), Yoichi tomimura (1992) also used slightly the same technique for extracting the starch and sugars form oil palm trunk. According to Yoichi tomimura (1992), the wood samples from 25-year-old palm trunks were debarked and cut into small chips which were then crashed in order to separate vascular bundles from parenchyma. Less than 200 mesh size of