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Oil Palm (*Elaeis guineensis*) Trunk as a Resource of Starch and Other Sugars

[1]P.S. H'ng, [1]L.J. Wong, [1]K.L. Chin, [1]E.S. Tor, [1]S.E. Tan, [2]B.T. Tey and [3]M. Maminski
[1]Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[2]Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[3]Faculty of Wood Techonology, Warsaw University of Life Sciences-SGGW,
159 Nowoursynowska St. 02-776 Warsaw, Poland

Abstract: Large quantities of oil palm trunks are available annually during the replanting activities when the oil palm tree passed their economic age, on an average after 25 years are replace with young trees. Basically the oil palm trunks contains about 18- 21% of lignin, 65-80% of holocellulose (a-cellulose and hemicellulose) and quite significant amount starch. This work is aimed to determine the total extractable starch and sugars content from oil palm trunks by using steeping method and dilute acid hydrolysis. The effect of different oil palm trunk powder size on starch, xylose and glucose yield was evaluated. The effect of extraction parameter for each extraction method on the yield of starch and sugars were studied. The highest starch yield was obtained when steeped in the presence of lactic acid, while the highest xylose yield was obtained by 60 min hydrolysis of 60 mesh of oil palm powder with 2% sulfuric acid. For glucose yield, hydrolysis efficiency of 82% was obtained for conversion of oil palm trunk to glucose using two-stage concentrated sulfuric acid hydrolysis. Conclusively oil palm trunk can be considered as a resource of substantial amounts of starch and sugars.

Key words: Oil palm trunk, starch, xylose, glucose

INTRODUCTION

Until year, 2009 4.69 million ha of land which is equal to 20% of Malaysia total land area, have been used for oil palm plantation (Anonymous, 2010). Usually the trunks generated from replanting activity is left on the plantation site or burned after replanting which causes some environmental problems. There are reports on application of the trunk especially for veneer and plywood production being reported (Hamid *et al*., 2008). Nonetheless the applicability of oil palm trunk in plywood production is laborious and not easy due to great variations in physical and mechanical properties which may cause many difficulties during processing and application. As Erwinsyah (2008) reports the densities vary from 140 to 600 kg m^{-3} within one trunk. Moreover, numerous studies demonstrated that oil palm wood on drying was a subject of shrinkage checking, warping, twisting and collapse (Lim and Gan, 2005; Mokhtar *et al*., 2008).

This may be attributed to the morphology and anatomy of palm species. Oil palm which is monocotyledon species does not posses any vascular cambium, so it does not increase in diameter with age. The typical feature is the distinct occurrence of the primary vascular bundles that are randomly embedded in the parenchyma group tissues. This is the key difference between oil palm and non-monocotyledon species wood. Bakar *et al*. (2006) reported that the amount of available oil palm wood is estimated on 10.8 - 11.6 million m^3.

Therefore, oil palm trunk seems to be a bioresource which can be entirely converted into valuable chemicals and products. The most economic conversion of oil palm wood to chemical products is production of sugars or other building blocks for organic synthesis (Rahman *et al*., 2006; Kosugi *et al*., 2010). 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). Oil palm wood consists of starch (3-5%) which is present naturally in most of the palm species as well as of C5 sugars and C6 sugars fixed in long chains of hemicelluloses and cellulose.

There are a few processes suitable for extracting starch C5, C6 sugars steeping method to extract starch (Perez *et al*., 2001), dilute acid hydrolysis to extract xylose (Dominguez *et al*., 1997) and concentrated acid hydrolysis to obtain glucose (Kusama, 1960). As mentioned earlier, the processes used to extract starch xylose and glucose were widely reported and

Corresponding Author: P.S. H'ng, Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

investigated. Nonetheless, the efficiency of these processes on oil palm trunk still remains unknown. Hence the efficiency of recovery processes for starch, xylose and glucose of oil palm trunk needs to be evaluated. It seems essential to investigate whether oil palm wood can provide as large amounts of starch and sugars as the recognized sources like sugar cane, corn, sorghum, wheat barley or potatoes. In this study the effect of variable process parameters on the yield of starch, xylose and glucose recovery was evaluated.

MATERIALS AND METHODS

The 20-year-old oil palm trunks were felled from Taman Pertanian Universiti Putra Malaysia (UPM) forest. The trunks were debarked chopped into chips size (ca. 20×20×20 mm^3) and grinded into powder. The powder was sieved to obtain size of 20, 40 and 60 mesh and oven-dried at 103°C to 5% moisture content prior to further work-up.

Chemical composition of oil palm wood was determined using the TAPPI standards: T222-74 for lignin TS os-73 for extractives, T203 os-61 for cellulose. Whereas, hollocellulose was determined using procedure proposed by Wise and Addieco (1946). All the experiments were carried out in triplicates.

Starch was extracted using two steeping methods with or without 0.5% lactic acid addition. In the first method 3.0 g of powdered palm wood (20, 40 or 60 mesh size) were soaked with 0.2% sodium metabisulphite ($Na_2S_2O_5$) solution at room temperature 26±2°C for 24, 36, 48 or 60 h In the second method, powdered palm wood was soaked with a mixture of 0.5% lactic acid and 0.2% sodium metabisuphite solutions (1:5 w/w). The samples were then steeped at room temperature 26±2°C for 24, 36, 48 or 60 h. Steeping medium was then filtered off. The residue was washed with 150 mL of distilled water. Finally starch content in the filtrate was determined by VIS spectrophotometry using iodine solution as indicator at wavelength of 650 nm (Humphreys and Kelly, 1961).

Xylose was recovered using diluted acid hydrolysis. Powdered palm wood samples were treated with 2, 4 or 6% sulfuric acid at the powder/acid weight ratio of 1:5. Mixture was then hydrolysed in autoclave at temperature of 115°C for 30 or 60 min. The samples were diluted with distilled water and insoluble solids were separated from aqueous solution by filtration. The hydrolysate was then neutralised to pH 7 before being brought for xylose determination by HPLC. Xylose content was analyzed on an HPLC (Shimadzu) using Varian PL-Hi Plex column and Refractive Index detector. Deionised water was used as mobile phase with flow rate of 0.4 mL $min^{-1}$and oven temperature was 80°C.

The percentage of xylose yield recovered from wood was calculated using the following formula:

$$\%\,\text{xylose} = \frac{\left[\text{dilution volume} \times \text{amound of xylose}\,(\text{g}\,\text{L}^{-1})\right]}{\text{dry wood weight} \times 100\%}$$

Glucose was recovered using strong acid hydrolysis. The 2-step procedure was described elsewhere (San *et al*., 2008). For the first stage hydrolysis the samples were treated with different acid concentrations of 60, 65, 70 and 75% at two different reaction times of 60 or 120 min at 60°C. At the second stage, 10 or 30% sulfuric acid for 60 or 120 min at 80°C were applied for hydrolysis. After hydrolysis was completed, the obtained hydrolysate was neutralized and analysed for glucose by OneTouch Ultra home blood-glucose meter.

RESULTS AND DISCUSSION

Starch yield: San *et al.* (2008) stated that the chemical composition of wood subjected to experiments was as follows: lignin 18.4%, extractives 3.1%, cellulose 47.5%, holocellulose 78.5%. The effects of steeping time and conditions on the starch yield are illustrated in Table 1. In general, higher starch yield was obtained when oil palm

Table 1: The mean percentage starch yield of different powder size, acid lactic concentration and steeping time by steeping process

Lactic acid (%, of the powder)	Mesh	Time (h)	Starch yield (%, of thepowder)
0.5	24	20	0.114^{i}
0.5	20	36	1.701^{a}
0.5	20	48	1.434^{ab}
0.5	20	60	1.413^{ab}
0.5	40	24	0.393^{efghi}
0.5	40	36	1.186^{bc}
0.5	40	60	1.433^{ab}
0.5	40	60	1.412^{ab}
0.5	60	24	0.506^{efg}
0.5	60	36	1.434^{ab}
0.5	60	48	1.371^{ab}
0.5	60	60	1.407^{ab}
0	20	24	0.204^{hi}
0	20	36	0.29^{fghi}
0	20	48	0.148^{hi}
0	20	60	0.218^{ghi}
0	40	24	0.918^{cd}
0	40	36	0.562^{ef}
0	40	48	0.355^{efghi}
0	40	60	0.327^{efghi}
0	60	24	0.57^{ef}
0	60	36	0.643^{de}
0	60	48	0.649^{de}
0	60	60	0.486^{efgh}

Mean with the same letter in the same column is not significantly different at $p \leq 0.05$

trunks steeped with the presence of lactic acid. The highest starch yield of 1.70% was extracted from 20 mesh powder size steeped for 36 h with addition of 0.5% acid lactic. However, it has been reported that the trunk might contain as much as 24% starch (Killmann and Lim, 1985). Ji *et al.* (2003) stated that the presence of lactic acid Rahman *et al.* (2006) stated that concentration of xylose in the resulting hydrolysate was ultimately decreased with increase in reaction time. Hence, some decomposition reactions may occur within such long duration. As shown elsewhere (Rahman *et al.*, 2007) hydrolysis of oil palm enhanced the separation and yield of starch and protein. Perez *et al.* (2001) found that higher starch yields were obtained from corn steeped in sulfur dioxide solution with lactic acid in comparison with that of without lactic acid. Thus as the data in Table 1 indicate the effect of mesh size and steeping time may be neglected.

Table 2: The mean percentage xylose and glucose yields of different powder size, acid concentration and reaction time by dilute acid hydrolysis process

Mesh	Acid (concentration, %)	Time (min)	Xylose (%, of the powder)	Glucose (%, of the powder)
20	2	30	8.21	6.56
20	2	60	14.64	12.02
20	4	30	12.20	7.60
20	4	60	13.35	8.46
20	6	30	9.41	5.54
20	6	60	10.48	7.48
40	2	30	14.53	21.79
40	2	60	14.34	8.68
40	4	30	11.25	11.44
40	4	60	7.82	9.86
40	6	30	12.84	11.38
40	6	60	13.99	6.39
60	2	30	14.87	25.47
60	2	60	19.17	22.42
60	4	30	18.63	19.17
60	4	60	11.45	21.87
60	6	30	12.41	18.82
60	6	60	12.14	19.26

Xylose yield: The highest xylose yield (19.17%) was obtained when 60 mesh wood powders was treated for 60 min with 2% sulfuric acid while the lowest xylose yield (7.82%) was obtained when 40 mesh wood powder was treated for 60 min with 4% sulfuric acid. According to Najafpour *et al.* (2007) longer reaction time is necessary if large solid sizes were used in hydrolysis. This is

Table 3: The glucose yield hydrolysed from oil palm trunk using concentrated acid hydrolysis method

	1st stage		2nd stage		
Entry No.	Acid concentration (%)	Reaction time (min)	Acid concentration (%)	Reaction time (min)	Glucose yield (%)
1	60	60	10	60	49.62
2	60	60	10	120	56.09
3	60	60	30	60	76.00
4	60	60	30	120	70.36
5	60	120	10	60	48.71
6	60	120	10	60	53.79
7	60	120	10	120	64.68
8	60	120	30	60	70.96
9	65	60	30	120	40.13
10	65	60	10	60	48.02
11	65	60	10	120	56.35
12	65	60	30	60	56.65
13	65	120	30	120	37.08
14	65	120	10	60	40.10
15	65	120	10	120	44.58
16	65	120	30	60	47.40
17	65	60	30	120	29.29
18	70	60	10	60	38.26
19	70	60	10	120	45.57
20	70	60	30	60	42.51
21	70	120	30	120	15.78
22	70	120	10	60	19.69
23	70	120	10	120	24.45
24	70	120	30	60	25.60
25	75	60	30	120	10.19
26	75	60	10	60	6.19
27	75	60	10	120	12.21
28	75	60	30	60	15.66
29	75	120	30	120	0.00
75	75	120	10	60	0.00
30	75	120	10	120	0.00
31	75	120	30	60	2.29
32	75	120	30	120	1.90

Note: The oil palm trunk powder size = 40 mesh size

because larger particle size with lower surface area to volume ratio will slow down the penetration of acid into solid particle. The results shown in Table 2 remain in accordance with that observation. However as shown in Table 2, 30 min reaction time was sufficient to extract considerable amount of xylose but acid concentration preferably should not exceed 4%. Higher acid concentrations, due to the prolong reaction time, probably degraded xylose to its by- products. Study by the empty fruit bunches with 2% sulfuric acid gave optimum xylose yield.

Glucose yield: Optimum cellulose conversion to glucose with the hydrolysis efficiency of 76%. Table 3 was obtained using two-stage sulfuric acid hydrolysis at elevated temperature. At the first stage hydrolysis, wood was treated with 60% sulfuric acid at 60°C for 30 min and subsequently subjected to 30% sulfuric acid at 80°C for 60 min considered as the second stage hydrolysis (San *et al*., 2008).

It should be also noted that acid concentrations above 60% especially when reaction times were prolonged- resulted in significant decrease in glucose yields (entries No. 13-28). In extreme case yield was close to 0% (entries No. 29-32).

CONCLUSION

It was shown that waste oil palm trunk, when properly treated, can be a renewable resource of starch, xylose and glucose which can be recovered by mild acid hydrolysis of wood. Although the yields are affected by many variables like powder particles size acid concentration reaction time and temperature further research and optimization of the process is reasonable due to its low-cost simplicity and abundance of feedstock.

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