Research and Development of Oil Palm Biomass Utilization in Wood-based Industries

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INTRODUCTION

The Malaysian oil palm industry started in 1917 and grew slowly until the late 1950s, when the agricultural diversification policy resulted in switch over from rubber to oil palm. From then, the industry grew rapidly, and presently, very little room remains for any significant increase in oil palm plantations in Peninsular Malaysia. As such, all future growth is expected to be in Sabah and Sarawak. At present, the total area under oil palm cultivation is about 3.5 million hectares, while total palm oil production for the year 2001 was 11.8 million tonnes. Despite the huge production, the oil consists of only a minor fraction of the total biomass produced in the plantation. The remainder consists of a huge amount of lignocellulosic materials in the form of fronds, trunks and empty fruit bunches. The year 1985 is considered as the start of a major replanting era in the oil palm industry, and from 1985 to 1995, there was a steady increase in oil palm replanting. By 1997, the replanting era reached its maximum, yielding over 27 million tonnes of biomass. As such, the oil palm industry must be prepared to take advantage of the situation and utilize the available biomass in the best possible manner.

PRODUCTION OF OIL PALM BIOMASS

The amount of biomass produced by an oil palm tree, inclusive of the oil and lignocellulosic materials is on the average 231.5 kg dry weight yr^{-1}. Each tree produces fresh fruit bunches which contain oil weigh only about 90.5 kg or 39% of the total biomass produced annually. Assuming that crude palm oil extraction rate is 22% and palm kernel oil is 1.6% of the bunch weight, then the total oil produced is 21.36 kg. This is only a mere 9.2% of the total biomass. It is obvious that the amount of presently usable portion is only a small fraction of the total biomass produced in a year. Thus, it will be a good strategy for the industry to also generate income from the lignocellulose portion of the biomass; while keeping the plantation unaffected due to the removal of these materials.

Trunks and Fronds

Oil palm is replanted, on an average, after 25 years. During replanting, the bole length of felled palm trunk is in the range of 7 m to 13 m, with a diameter of 45 cm to 65 cm, measured at breast height. The volume of this oil palm trunk can be estimated by using the Smalian formula which is equal to 0.4057 + 0.000040597 x diameter x height. Basically, the trunk is made up of strands of vascular bundles of fibrous sheath surrounding xylem and phloem cells which are embedded in ground parenchymatous tissue. In addition, it was found that there is a high density gradient between the centre core and the peripheral zone with an average density of 0.37 g cm^{-3}. *Table 1* indicates the area under replanting from year 1985 to 2000. It is estimated that the average dry weights of felled fronds and trunks were 115.4 kg and 600 kg respectively. Assuming that the average planting density is 145 palms ha^{-1} and 95% of the palms are still remaining at the replanting age, the estimated availability of oil palm trunks and fronds is shown in *Table* 2.

In addition to the fronds obtained at felling on replanting, palm fronds are also obtained from pruning done during the harvesting of the fresh fruit bunches. Unlike felled fronds (at replanting), the average dry weight for pruned fronds was found to be 6.5 kg and the quantity of pruned fronds was greater than that of felled fronds.

Empty Fruit Bunches and Palm Pressed Fibre

At the palm oil mill, the sterilized fresh fruit bunches go through a threshing process to separate the sterilized fruits from the bunches. The fruit bunch is made up of a main stalk and numerous spikelets with sharp spines at their tips. The freshly sterilized empty fruit bunches contain 65% water, 30% dry matter and 2% to 5% of crude

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TABLE 1. REPLANTING AREA (ha) OF OIL PALM PLANTATION FROM YEAR 1985 TO YEAR 2000

Year	West Malaysia	East Malaysia	Total
1985	3 035	8	3 043
1986	4 321	130	4 451
1987	5 500	368	5 451
1988	7 700	824	5 868
1989	9 650	1 938	11 588
1990	11 500	4 204	15 704
1991	21 150	7 342	28 492
1992	30 250	9 932	40 182
1993	35 500	12 822	48 322
1994	39 400	15 356	54 756
1995	37 150	14 872	52 022
1996	38 550	13 220	51 770
1997	62 100	11 138	73 238
1998	79 000	9 996	88 996
1999	76 100	8 628	84 728
2000	75 800	7 794	83 594

Source: Mohd Husin *et* al. (1985)

TABLE 2. ESTIMATED AVAILABILITY OF OIL PALM TRUNKS AND FRONDS ($1x10^6$ t dry weight)

Year	Trunk	Felled-frond	Pruned-frond	Total
1985	0.26	0.05	13.29	13.60
1986	0.37	0.07	14.21	14.64
1987	0.49	0.09	14.97	15.55
1988	0.72	0.12	15.96	16.80
1989	0.97	0.19	16.43	17.59
1990	1.32	0.25	16.92	18.49
1991	2.39	0.46	17.35	20.20
1992	3.29	0.64	17.64	21.57
1993	4.06	0.77	17.85	22.68
1994	4.60	0.88	17.89	23.37
1995	4.37	0.83	18.17	23.37
1996	4.36	0.83	19.09	24.28
1997	6.15	1.17	19.39	26.71
1998	7.48	1.42	18.18	27.08
1999	7.12	1.36	17.92	26.40
2000	7.02	1.34	17.85	26.21

Source: Mohd Husin *et al.* (1985)

palm oil. The empty fruit bunches consisting of vascular bundles which are embedded in parenchyma tissues are similar to that found in the trunks and fronds. The vascular bundles of empty fruit bunches are quite springy and flexible. At the palm oil mill, the empty bunches are mainly incinerated to produce bunch ash which contains a high percentage of potassium. The ash is distributed back to the field as fertilizer for the palms. However, the incineration process results in severe air pollution problems. In some oil palm mills, the empty bunches are pressed to reduce their moisture content and burnt as fuel to generate steam to be sold to nearby factories.

Palm pressed fibre is obtained during the pressing of sterilized fruits and contains about 60% w/w dry matter. Though produced in large quantities, the availability of the palm pressed fibre is limited because it is presently utilized in the mill as a source of energy. The estimated availability of empty fruit bunches and palm pressed fibre is presented in *Table* 3.

MAJOR WOOD-BASED PRODUCTS THAT CAN BE MANUFACTURED FROM OIL PALM BIOMASS

There are several wood-based products from oil palm biomass that have been successfully studied. The major ones are described below:

Pulp and Paper

***Kraft* and Kraft *AQ*.** Untreated whole empty fruit bunch (EFB) is digested, and the pulp yield is between 26% to 32%, with a very high lignin content of over 6%. The pulp brightness is between 35% to 40%. However, the pulp yield improves significantly (to over 40%) when the EFB is pretreated with 3% soda for 1 hr at 50°C to 60°C. The addition of anthraquinone (AQ) (Kraft-AQ pulping) improves the yield only slightly but the lignin content is reduced to about 1% only.

The properties of the pulp are superior to those of hardwood Kraft pulp (KP) such as beech and birch. The brightness is good (40%), compared to hardwood pulp (25%-30%). The breaking length, tear factor and folding endurance are within the upper range of the typical hardwood unbleached Kraft pulp (UKP). The fibre length is about 0.9 mm.

Single-stage hypochlorite bleaching of EFB Kraft-AQ pulp at 3% available chlorine, improves the brightness to 79.4%, with about 6% of the pulp lost. Multi-stage bleaching (four-stage CEHD) increases the brightness to 86.5% with also a loss of 6% pulp. The EFB bleached Kraft pulp (BKP) demonstrates almost the same strength as those of hardwoods.

For oil palm fronds (OPF) pretreated and pulped in a similar manner as the EFB, the optimum active alkali (AA) was 15% and AQ 0.1 %, and the yield obtained was about 44%. However, pulp brightness is low at only 20%. The strength properties are excellent

TABLE 3. ESTIMATED AVAILABILITY OF OIL PALM EMPTY FRUIT BUNCHES AND PRESSED FIBRES (1 x10^6 t dry weight)

Year	Empty bunches	Pressed fibres
1985	1.60	1.67
1986	1.75	1.72
1987	1.87	1.95
1988	1.99	2.07
1989	2.09	2.17
1990	2.18	2.27
1991	2.23	2.33
1992	2.26	2.37
1993	2.28	2.38
1994	2.27	2.37
1995	2.27	2.36
1996	2.27	2.37
1997	2.25	2.35
1998	2.22	2.32
1999	2.20	2.30
2000	2.16	2.26
Total	**33.89**	**35.26**

Source: Mohd Husin *et al. (1985).*

and are only slightly lower compared to softwood UKP The breaking length is over 9.0 m, and the folding endurance is 150. The fibre length ranges from 1 mm to 2 mm. The average length of fibre is 1.35 mm. From this study, it was concluded that strong pulp can be obtained from fronds using Kraft-AQ pulping.

Single-stage hypochlorite bleaching indicates that the brightness of the OPF pulp can be increased to 60% using single-stage hypochlorite with 3% available chlorine. However, increasing the available chlorine to 10% only produces up to 80% brightness. In two-stage hypochlorite bleaching, the brightness increases to 65% from 26% using only (1 + 1)% available chlorine. The pulp lost during bleaching is 3.6%. The KP-AQ of oil palm trunk (OPT) was evaluated both from the whole trunk and parenchyma-free vascular bundles. The pulping condition was similar to that for OPF and EFB as mentioned earlier. The total pulp yield was about 50%. The yield obtained from the whole trunk was slightly higher than that obtained from the parenchyma-free vascular bundles. The brightness was low at about 20%. The pulp strength was better than that of hardwood kraft pulp. The presence of parenchyma cells increased the pulp yield but reduced the strength properties.

Chemi-Thermo Mechanical Pulping/Thermo Mechanical Pulping (CTMP/TMP)

The CTMP pulp obtained from EFB indicates that it has rather low brightness (30% hunter) as compared to softwood or bagasse CTMP pulp. However, the strength characteristics are superior to bagasse and some, such as tear strength and folding endurance are far greater than those of commercial bagasse or softwood CTMP. For OPF, the pulp is even darker (20% hunter) but yield is slightly higher. In general, TMP of untreated fronds shows low strength properties. However, further treatment with 2% NaOH increases the breaking length. Tear factor and folding endurance decreased appreciably, while the opacity decreased slightly.

Since the TMP of both EFB and fronds are of poor brightness, bleaching becomes an important part of the CTMP process, especially when the pulp is meant for newsprint and printing paper. It is noted that TMP from EFB is slightly easier to bleach compared to the fronds.

Medium Density Fibreboard (MDF)

The manufacture of medium density fibreboard (MDF) was also attempted using EFB in 1986. In this trial, it was observed that EFB can be used for the manufacture of MDF. The strength properties measured from its compression strength exceed the 200 kg cm^{-2} stipulated in JIS A 1408 for fibreboard. However, the board needs to be manufactured at higher density, i.e. higher than 800 kg m^{-3}. Thus, EFB should be suitable for making high density fiberboard.

In another study on MDF, the board produced from OPT can easily pass the minimum requirement as stipulated in the Euro MDF Board Standard. The board manufactured from OPF failed in Modulus of Elasticity (MOE) and Modulus of Rigidity (MOR). This problem can be remedied by modification of the density gradient. However, boards manufactured from EFB, while, failing in blending strength, also demonstrated poor dimensional stability and high silica content. MDF manufactured from trunk with its light colour will compare better than that manufactured from fronds, which has dark spots on the surface.

Blockboard

Blockboard can be manufactured from OPT as the centre core. It is lighter than blackboard manufactured from normal wood. The physical and mechanical properties indicate that blockboard from OPT is suitable for non-load bearing applications, such as paneling and furniture applications.

Patticleboards

Particleboards with chemical binders. A study on homogenous particleboards and three-layered particleboards from oil palm trunk vascular bundles indicated that at 700 kg m^{-3} and 8% adhesive content, the boards passed the minimum standard stipulated in the BS 5669:1979 Type 1. For the three-layered boards, it was necessary to have 10% resin content for surface particle and 8% for the core with an overall density of 700 kg m^{-3} in order to pass the minimum requirements as stipulated in the standard.

At Bison-Werke, Germany, graded density particleboard were manufactured which included fines (from ground parenchyma tissue) of oil palm trunk. It was noted that the addition of at least 1% wax is necessary to pass the minimum standard stipulated in DIN 68763 for building construction. Also the board should have density higher than 700 kg m^{-3}, with resin content of 8% surface and 10% core.

The use of EFB for particleboard was attempted at Universiti Institut Teknologi MARA (UiTM) based on the British Standard BS 5669, 1989. From this study, it was found that the bending strength can be improved by increasing the resin content and the dimensional stability was improved by the addition of wax. It was concluded that EFB can be an important source of particles for particleboard manufacture.

Moulded particleboard The process of manufacturing moulded particleboard is generally the same as normal particleboard, except that the particle mat is placed in a mould with the desired shape before pressing. OPT and fronds have also been used as raw materials in moulded particleboard manufacture. Several items, such as table tops of various sizes and shapes and chair seats, have been successfully tried in industrial scale plant. In these trials, boards manufactured using 18% resin content and density of 700 kg m^{-3}, had sufficient material strength to pass the British Standard BS 5669:1979 Type 1 particleboard. The advantage of producing table tops in this manner is that it minimizes or eliminates the successive processing steps as normally done using conventional process producing similar products.

Mineral-bonded particleboards

a. Cement-bonded particleboard (CBP)

In the early part of the study, many attempts were made to manufacture cement boards from oil palm biomass but these efforts achieved little success. This was attributed to the presence of high carbohydrate content - ranging from 1.8% to 9.8% of the total free sugar throughout the various height and zones of the OPT. In ordinary wood, soluble carbohydrates and phenolic components have been shown to affect the setting of cement. Therefore, the level of carbohydrates must be lowered for successful cementboard manufacture.

In practice, several methods have been used to reduce the amount of sugars and starch in wood particles, of which, soaking treatment and piling for a period of time are common. Particles from OPT treated in such a manner showed reduced sugar content. The cementboard manufactured from soaked pretreatment indicated better properties, passing the above-mentioned standard. Piling treatment however, indicated poor board properties and it failed in many of the properties under the standard.

b. Gypsum-bonded particleboard (GBP)

Oil palm biomass can also be used as raw material for gypsum-bonded particleboard. In wood, polyporic compounds, especially hydrolysable tannin and amino acid, are responsible for the retarding effect of gypsum. In one study, OPT GBP were made using Thai gypsum (TG) casting plaster and the properties were compared to those of commercial board. The results indicated that GBP with density of 1000 kg m^{-3} failed to meet commercial requirements. The water absorption values were too high and the boards cannot be used for external purposes. However, boards with high density easily pass the minimum requirement.

c. Planting medium

Oil palm biomass can also be utilized as a planting medium, as an alternative to rockwool. Initial study on planting medium from oil palm biomass that have been planted with tomatoes and brinjal showed that these plants were able to sustain their growth. The advantages of using planting medium from oil palm biomass were biodegradability, good water-fertilizer retention and availability of readily renewable resources.

TECHNICAL PROBLEMS OF USING OIL PALM BIOMASS

Though oil palm biomass is suitable for use in the manufacture of most wood-based products such as composite products, pulp and paper, these applications are not without problems. Some of the major problems which have surfaced in many discussions are as follows:

Storage

Oil palm biomass is highly susceptible to fungal attacks during storage. Such attacks can cause discoloration, which may affect the final products. Thus, storage problems need to be solved before setting up plant for wood-based products manufacturing.

Parenchyma Cells

Parenchyma ground tissue which cements the vascular bundles together is undesirable for the manufacture of wood-based products like pulp and composite boards. In pulp manufacture, these tissues consume chemicals and produce fines which may be lost during screening. The rounded parenchyma also reduces the paper strength properties. In particleboard manufacturing, it may interfere with the bonding between particle and will reduce strength properties.

High Silica Content

The high silica content causes difficulties in cutting and chipping of the biomass into desired shapes and sizes. It has been reported that dulling of knife blades occur after only 5 min during chipping of OPT. The wood-based products obtained from oil palm biomass could also inherit this property unless the silica content is first reduced within the tolerable limit.

High Moisture and Low Bulk Density

The apparent weight of fresh OPT is not due to the density of the biomass, but because of the presence of high moisture content. The transportation cost of fresh oil palm biomass from the field to the factory will also include cost for the transportation of moisture (about two to three times the weight of biomass) and parenchyma cells (about 30% of the biomass). The bending of fronds also reduces the bulk density when piled up for transportation - thus space is often not optimally utilized. Therefore, the transportation cost would be very high.

ADVANTAGES AND DISADVANTAGES OF UTILIZING OIL PALM BIOMASS FOR WOOD-BASED INDUSTRIES

In general, the main objective of the oil palm plantation is to produce good quality fresh fruit bunches with high oil extraction rate. The shell and fibre are required to a certain extent by the mills as a source of energy. On the other hand, the production of large amounts of OPF and EFB may be viewed as undesirable, as they incur cost to the plantation. The OPT, which increases in height over time, also incurs costs both in the harvesting and replanting process. Thus, the extraction of the biomass from the plantations/mills for the wood-based industry would obviously be an advantage. The utilization of the biomass reduces the disposal costs, and at the same time can provide additional income to the plantation.

The indiscriminate removal of biomass from the plantation can cause reduction of organic matter and nutrients supply to the palm. Apart from organic matter and nutrient loss, it is also claimed that biomass laid out in the plantations conserves water and prevents erosion. There may be a need to adopt new management systems for the removal of biomass from the fields. The loss of organic matter from the soil can be overcome by planting suitable cover crops that can thrive under the oil palm. The loss of nutrients can be supplemented by the addition of fertilizer. It can be argued that the slow release of nutrients from the oil palm biomass may not be comparable to the chemical fertilizer applications that can easily be washed away by rain. Perhaps different methods of application are required to account for the losses of the nutrients.

CONCLUSION AND RECOMMENDATIONS

The effort to utilize oil palm biomass as raw material for wood-based industry started over a quarter of a century ago. Given the time and circumstances, very little achievement has been obtained. These materials pose the scientists with very complex problems, entirely different from those already experienced from working with normal wood. However, some products that can be manufactured from oil palm biomass have recently been identified and these have good potential for industrialization.

The economic situation and other circumstances indicate that the utilization of oil palm biomass at industrial level is inevitable in the near future. This would require the removal of biomass from the plantations. However such an operation could lead to the depletion of organic matter, and in the long run may be detrimental to the oil palm industry. Thus, agronomists, soil scientists and plantation managers should consider the planting of suitable cover crops that can survive under the shade of oil palm trees to supplement the organic matter loss in the soil. Dosage and frequency of fertilizer application must be reviewed due to the depletion of the organic matter.

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