PULPABILITY OF OIL PALM EMPTY FRUIT BUNCH VIA ALKALINE PEROXIDE TREATMENT

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PULPABILITY OF OIL PALM EMPTY FRUIT BUNCH VIA ALKALINE PEROXIDE TREATMENT

by

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LIST OF ABBREVIATIONS

EFB	Empty fruit bunches
OPF	Oil palm fronds
odmt	oven-dried metric tonne
OPT	Oil palm trunk
MDF	Medium density fibreboard
APMP	Alkaline Peroxide Mechanical Pulping
JIS	Japanese Industrial Standards
ASEAN	Association of Southeast Asian Nations
DP	Dissolving pulp
CTMP	Chemi-Thermo-Mechanical Pulping
MC	Moisture content
FAS	Fiber Analysis System
CSF	Canadian Standard Freeness
SEM	Scanning Electron Microscopy
TAPPI	Technical Association of the Pulp and Paper Industry
ANOVA	Analysis of variance
%	percent
^{o}C	degree celsius
mm	millimeter
N	Newton
Pa	Pascal
ad	air-dried
od	oven-dried

KEBOLEHAN MEMULPA TANDAN KOSONG KELAPA SAWIT MELALUI RAWATAN PEROKSIDA BERALKALI

ABSTRAK

Pengaruh tahap kepekatan peroksida beralkali (AP) dan masa pra-rawatan terhadap kertas yang dihasilkan daripada tandan kosong kelapa sawit dikaji. Impregnasi tandan kosong kelapa sawit dengan peroksida beralkali diperhatikan pada tiga tahap kepekatan yang dikategorikan kepada tinggi (5% H_2O_2: 4% NaOH), sederhana (2.5% H_2O_2: 2% NaOH) dan rendah (1.5% H_2O_2: 1% NaOH). Tindakbalas juga diperhatikan pada pelbagai masa pra-rawatan iaitu pada 0 minit, 10 minit, 20 minit, 30 minit, 40 minit, 50 minit, 60 minit dan 120 minit. Pra-rawatan peroksida beralkali dilakukan pada suhu malar (70^{o}C) dengan nisbah tetap tandan kosong kelapa sawit kepada likur, 1:10, masing-masing, berdasarkan berat kering ketuhar tandan kosong kelapa sawit. Komposisi kimia gentian tandan kosong kelapa sawit ditentukan dan dijadikan sebagai data asas dalam kajian. Analisis menunjukkan peratusan hasil meningkat secara ketara dengan meningkatnya tahap kepekatan peroksida beralkali dan masa rawatan. Walaubagaimanapun, sifat-sifat gentian (panjang gentian dan ketebalan gentian), nombor kappa dan kebebasan (freeness) didapati menurun dengan peningkatan tahap kepekatan peroksida beralkali dan masa rawatan. Penggunaan tahap kepekatan peroksida beralkali yang lebih tinggi dengan masa rawatan yang lebih lama menghasilkan ketumpatan yang lebih baik berbanding dengan tahap kepekatan yang lebih rendah dengan waktu rawatan yang lebih pendek. Bagaimanapun, corak ini berbeza dengan ketebalan. Sifat mekanikal seperti kekuatan tensil, kekuatan lipatan, kekuatan pecahan dan jarak sifar (zero span) meningkat secara signifikan apabila tahap kepekatan yang lebih tinggi dengan waktu rawatan

yang lebih lama digunakan. Corak yang sama juga didapati pada ujian kecerahan tetapi kecerahan yang maksimum didapati pada masa 60 minit masa rawatan. Konsisten untuk sifat mekanikal dan optikal, peningkatan secara pesat bagi pembangunan sifat pulpa dan kertas diperhatikan pada tempoh pertama 40 minit hingga 60 minit masa rawatan dalam peroksida beralkali. Pemerhatian ini mencadangkan bahawa kekuatan tindakbalas maksimum oleh peroksida beralkali kepada tandan kosong kelapa sawit dapat diperhatikan pada tempoh masa tersebut. Kondisi yang dikenalpasti ini juga menghasilkan fibrilasi luaran yang mencukupi untuk ikatan hidrogen bagi membentuk jaringan kertas seperti yang dibuktikan dari imbasan mikroskop electron (SEM).

PULPABILITY OF OIL PALM EMPTY FRUIT BUNCH VIA ALKALINE PEROXIDE TREATMENT

ABSTRACT

The effects of alkaline peroxide (AP) concentration level and pre-treatment time on oil palm empty fruit bunch (EFB) were studied. The impregnation of EFB with alkaline peroxide was observed at three levels of alkaline peroxide concentration, which were categorized as high (5% H_2O_2: 4% NaOH), medium (2.5% H_2O_2: 2% NaOH) and low (1.5% H_2O_2: 1% NaOH). The reaction was also observed at various pre-treatment time which were 0 minute, 10 minutes, 20 minutes, 30 minutes, 40 minutes, 50 minutes, 60 minutes and 120 minutes. The experiment was performed at 70^{o}C with fixed ratio of EFB to liquor of 1:10 based on oven-dry weight of EFB. The chemical compositions of untreated EFB fibres were determined and served as baseline data of the study. The analysis showed that the yield percentage was increased significantly with the increasing alkaline peroxide concentration and treatment time. However, fibre characteristics (fibre length and fibre width), kappa number and freeness were found to decrease with the increasing alkaline peroxide concentration and treatment time. Application of higher alkaline peroxide concentration with longer treatment time offered better density compared to lower chemical concentration with shorter treatment time. However, this pattern was inversed with thickness. The mechanical properties such as tensile strength, folding endurance, bursting strength and zero span increased significantly when higher chemical concentration and longer treatment time were applied. The same pattern also was obtained for brightness as well but the maximum possible brightness was only obtained at the 60th minutes of alkaline peroxide treatment. Consistently for

mechanical and optical properties, a rapid increased in pulp and paper property development was observed in the first 40 minutes to 60 minutes of treatment in alkaline peroxide. This observation suggested that the maximum possible power reaction of alkaline peroxide to EFB could be reaped in the said duration. The identified conditions also offered adequate external fibrillation for hydrogen bonding in forming paper network as evident from scanning electron microscopy (SEM).

CHAPTER 1

INTRODUCTION

1.1 Introduction

The palm oil milling sector in Malaysia generates millions of metric tonne of oil palm wastes annually. These include the empty fruit bunch (EFB) generated at the oil mill, the oil palm fronds (OPF) that are available throughout the year and the oil palm trunks (OPT) generated at felling. According to Law *et al*. (2007), 36 million tonnes (odmt) of these wastes came from the empty fruit bunch (EFB) alone and these were processed further to get dry vascular bundles which are also known as dried long fibre and packed into bales for storage and transportation for further conversion to various other products.

Valuable fibres attained from EFB are presently used for developing value-added products such as wood composite product, medium density fibreboard (MDF) and fibreboard (Ghazali *et al*., 2006). Owing to its lower lignin content relative to OPF and OPT, high cellulose content, moderate level of extractives and acceptable level of starch, EFB has been the most suitable raw material for pulping and paper making, as compared to the other two oil palm derivatives, OPT and OPT. Besides reducing environmental impacts from waste accumulation, EFB utilization for pulp production can also help Malaysia to be independent of imported fibre (Fang *et al*., 2000). One potential way of materializing the idea is by adapting the concept of alkaline peroxide mechanical pulping (APMP) on the raw material. There are two basic concepts which were commonly applied by previous researches in APMP technique. One was by applying alkaline peroxide treatment on chips of fibres, to allow the bleaching or brightening reactions to complete before undergo refining process. The other basic concept was to apply all the alkaline peroxide in the refiner, either without pretreatment or pretreatment with stabilizers prior to the alkaline peroxide application in the refiner. This research applied one of the basic concepts of APMP technique by pre-treated the segmented EFB fibres using various alkaline peroxide levels at different treatment time before undergo refining process.

APMP is a process that combines bleaching and pulping in one process with alkaline peroxide as the main driving agent. This process was introduced by Andritz Sprout-Bauer, United States of America in 1989 and has been recognized as the most efficient chemi-mechanical pulping technique for hardwood. The pulping process had gained worldwide research and industrial interests due to its outstanding features like environmental friendliness analogous to mechanical pulping but offering pulp quality comparable to chemical pulp (Fang *et al*., 2000). Furthermore, APMP is proven cost-effective due to elimination of a separate bleach plant and it is this that helps reduce the overall capital investment (Ghazali *et al*., 2006). In addition, APMP is a flexible pulping process in that it is adaptable to a variety of biomass including such non-wood materials as bagasse, kenaf, jute and straw as shown in Table 2.9 (Ghazali, 2006).

Despite its excellent features, APMP is still not operationally adopted in the Malaysian pulp and paper industry due to the need to thoroughly study the process quality and cost wise. For this reason, more researches and investigations are underway in order to understand the process comprehensively. By adapting the concept process of APMP, the aims of this study are to examine the effects of various treatment time and levels of chemical concentration on the properties of EFB fibre, pulp and hand sheets, which are hereby presented.

1.2 Objectives

The objectives of this research are summarized below:

1. To determine the chemical properties of EFB vascular bundle.
2. To determine the effect of different concentration level of pre-mixed H_2O_2 and NaOH, and the effect of treatment time on empty fruit bunch alkaline peroxide pulp and paper properties.

CHAPTER 2

LITERATURE REVIEW

2.1 The Origin and Historical Development of Paper and Paper Making

Paper is defined by paper industry as "*A sheet or continuous web of material formed by the deposition of vegetable, mineral, animal or synthetic fibres or their mixtures with and without the addition of other substances, from suspension in a liquid, vapour or gas in such a way that the fibres are intermeshed together. Paper may be coated, impregnated, printed or otherwise converted, during or after its manufacture, without necessarily losing its identity as paper"* (Thomas, 1965). Noah Webster also defined paper as "*a substance made in the form of thin sheets or leaves from rags, straw, bark, wood or other fibrous material, for various uses*" (Hunter, 1978). These definitions make clear an essential characteristic of paper, namely, that it is a network of a large number of holes enclosed by fibres.

An outstanding development of paper making over centuries has made paper a versatile material with many uses. In the earliest days, people worked hard carving pictures and symbols into the walls of caves, stones, clay tiles, bones, metals, skin, leaves of certain plants, waxed wooden tablets, linen and silk fabrics for the transmission of their experiences and ideas (Thomas, 1965). These earliest writing media of ancient times were being gradually replaced by the Egyptian's early papers about 4000 years ago. The Egyptians discovered how to make a writing surface out of papyrus plant, which grew abundantly along the Nile, located in Egypt in that time. Not only the stalk of papyrus used as a writing substance, but also as building material and for the making of boats, mats, cords and sandals. Besides that, the origin word of “paper” was derived from the word “papyrus” (Hunter, 1978).

Before the invention of paper in China, strips of bamboo or wood were used for drawing and writing but these materials were difficult to write upon, difficult to store and consumed much space. During 105 AD (about 2000 years ago), a Chinese court official and scholar named Tsai’ Lun invented the process of paper making and he became revered as the patron saint of paper making. One Chinese record states that “*he first made paper by pulping fishing nets and rags. Later, he used the fibres of plants; any which proved sufficiently elastic in tension were used as the raw material of paper. The raw materials were first well boiled and then beaten into a mash. The resultant pulp was stirred into a pulp and spread on a straining frame or basket. When it formed a thin tissue, the resultant paper was then pressed with heavy weights”* (Thomas, 1965).

This great invention has become one of the “Four Great Inventions of Ancient China” (Wikipedia, 2010). Indeed, paper remained a secret of the Chinese until 751 AD until the capture of Chinese prisoners by Arabs Samarkand in the eight century (Thomas, 1965). The secret of paper making spread from China through the Islamic world and extended across the Near East and North Africa and then, entered into Europe production in the early 12th century (Wikipedia, 2010).

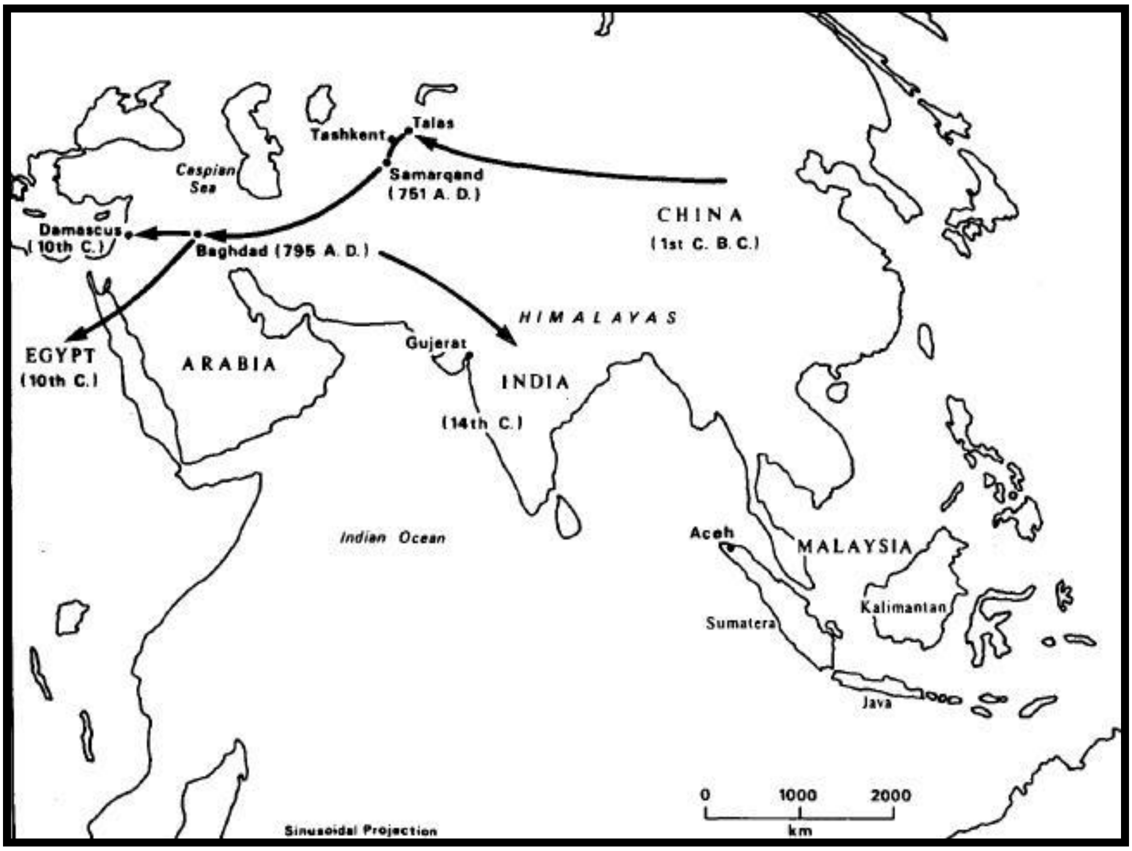

Figure 2.1 The spread of paper making (Jones, 1993).

2.2 Non-wood in Paper Making

Human have relied on herbaceous plants for paper stock for thousands of years. Historically, paper was made from non-wood such as rags but has been substituted with virgin fibre from trees as the primary raw material for pulp and paper manufacturing after the growth of industrialization in the mid to late nineteenth century (Anonymous, 2008). Today, wood has become the dominant fibre raw for pulp and paper as it contributes over 90% of the world's pulping capacity. The continued growth in paper consumption in order to fulfil the demand of paper and paper products, which is increasing day by day as well as the emergence of bio-fuel lead to a bigger demand for wood, hence, increase the destruction of intact-forest ecosystem, fragmentation of wildlife habitats, depletion of stratospheric ozone layer and contamination of air and waterways (Mardon, 2010).

These negative impacts have gained environmental concerns and hence, encouraged the national and international levels to find suitable substitutes for wood fibres. These reasons also served to increase the interest in non-wood sources for paper and other products, even in countries that have extensive forest resources. Non-woods are clearly necessary alternative as it offers viable, job-creating solutions to environmental problem caused by the harvesting of virgin wood for papermaking.

Millions of tonnes of waste residues are generated every year in farming practices throughout the world. These agricultural by-products, residues and non-wood fibres could substitute for primary wood consumption in diverse uses such as paper, particle boards and building materials. Channelling these excess residues into paper and other products would help prevent open burning of the residues that would otherwise contribute to air pollution and release of green gases (Anonymous, 2008). The use of non-wood fibres as an alternative source of producing pulp and paper could also help in reducing the demand in virgin wood pulp and become the best solution to overcome the shortage of short fibre raw materials facing by some countries such as China and Egypt.

Paper can be made from non-wood fibres such as hemp (Figure 2.2), grass (Figure 2.3), cotton (Figure 2.4), flax (Figure 2.5), kenaf (Figure 2.6), bagasse which made from sugar cane waste (Figure 2.7) and straw (Figure 2.8). These fibres already make up over half the virgin pulp production in some developing countries and are currently experiencing a revival in interest in developed countries too. However, the processing and characteristics of non-wood materials tend to be different from those of wood, offering significant challenges to their use (Laren *et al*., 1998).

Figure 2.2 Hemp biomass (Stoddart, 2009).

Figure 2.3 Grass biomass (Helicon,2010).

Figure 2.4 Cotton tree (Kushtush, 2004).

Figure 2.5 Flax tree (SERC, 2010).

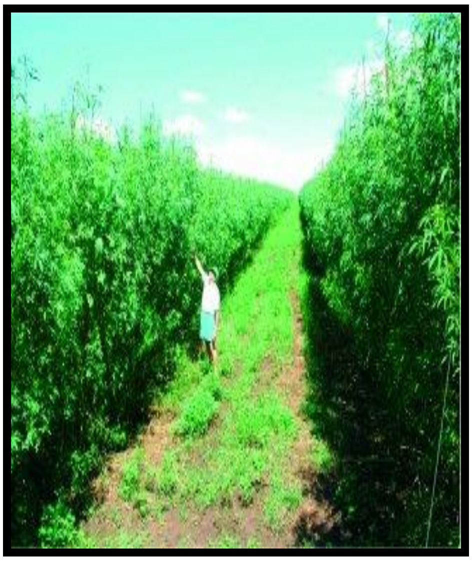

Figure 2.6 Kenaf tree (CSIR, 2009).

Figure 2.7 Bagasse biomass made from sugarcane waste (Monniaux, 2005).

Figure 2.8 A field of rice straw at Prospect Hill in Virginia, United States (CGRF, 2008).

According to Young (1997), non-wood plants contain lower lignin content in comparison to wood and the pulping of these non-wood fibres can reduce power consumption in pulp refining process and demands around 30% of chemical charge as there are generally easy delignified. The potential for reducing the energy consumption in refining was highly demanded as the conservation of energy is an essential step towards overcoming the rising problems of the worldwide energy crisis. Bleaching of non-wood fibres is also comparatively easy and contributes to a lower cost of production for some grades of paper made from non-wood plants. Savcor (2007) reported that higher pentosans, which are available in non-wood fibres could generate good bonding of fibres and this could give plenty advantages to the papermaking process. Besides that, Ververis *et al.* (2004) said that it is more economical to produce pulp from non-wood fibres in the existing wood pulp mills and this idea can help the industry to avoid making new investment including spending higher operating cost for building non-wood pulp mills.

Currently, plenty of researches are focusing on the potential of cellulose based fibres especially non-wood fibres in paper making process. Even though there are many advantages of using these non-woods, researchers also agree that these renewable sources also have some drawbacks. Non-wood fibres contain higher amount of inorganic materials in comparison to wood fibres and this is implied by the ash content. One of the major inorganic constituents in non-wood fibres is silica, which consist more than 50% of the inorganic materials in a non-wood fibre. Silica is especially known for problems pertinent to material handling pulp, washing and chemical recovery (Savcor, 2007).

2.3 Advantages and Disadvantages of Using Non-wood Fibres for Pulp and Paper Making

The advantages and disadvantages of using non-wood fibres for pulp and paper making are briefly summarized in Table 2.1 below.

Table 2.1 The Advantages and Disadvantages of Non-wood Fibres (Roberts, 1996)

	Advantages	**Disadvantages**
Fibre supply		
Based on annual or perennial fibres or agri-residues.	Reduces need to exploit natural forest and for tree plantations.	Maybe problems associated with monocultures of annual fibres for example, fertilizer and pesticide use, impact on crop rotations, biodiversity. This varies with fibre, area and management regime.
	Use of agri-residues in some cases makes use of what otherwise would be a waste product.	Use of agri-residues may reduce the fertility of the soil if some are not ploughed back in.
	Using agriculture land for annual fibres in developed countries can contribute to reducing food surpluses.	Replacing food crops with fibre crops could be detrimental in area where food security is a problem.

	Can alter amount of biomass produced annually.	Harvested over a short period, therefore, large storage space required to ensure year round supply. Significant deterioration problems may occur. Storage needs may also differ by types of biomass. Non-wood fibres tend to be bulkier than wood which increase transport and storage costs.
	Can support small scale mills, therefore a much lower level of capital investment is required. Small mills employ more people per tonne of pulp than large ones.	Unlikely to be able to support large scale mills, therefore do not get the benefits of economies of scale.
Contract with large number of growers required.	Provides growers with and additional/alternative income. May support rural employment and economic vialibility.	Dependent on growers. Fibre crops will only be grown and residues sold if farmers are convinced that the opportunity costs are higher and the risks and effort involved are lower than those for alternative crops. This may vary from year to year.

Production		
Lower proportion of lignin than wood.	Less energy required in comparison to pulp fibre. Less energy and chemicals required to bleach fibre.	If a chemical pulping method is used on the non-wood fibres, the lower amount of lignin results in less being able to be used as a fuel.
Higher proportion of silica than wood makes conventional chemical recovery systems inappropriate.	Opens wide opportunity for research on utilization of pulping bleach liquor.	If alternative treatments is not utilised mills are highly polluting and chemical costs will be higher due to lack of recovery. Appropriate production technologies may not be readily available and maybe more expensive than the wood equivalent.
	Alternative pulping systems such as APMP which reduce the need for chemical recovery may produce useful by-products.	Alternative pulping system tends to use more expensive chemicals.
Industry is dominated by wood pulp producers and is conservative.		Little interest, research or investment in non-wood fibres by industry. Non-wood fibres are perceived to be high risk. Paper makers are reluctant to make the required changes of their machinery to enable use non-wood pulp.

Demands	Niche markets for high priced speciality paper for which certain non-wood fibres have inherent advantages over wood.	Speciality market is small.
	Niche market for 'treefree' products for which premiums are payable.	Size on 'treefree' market is unclear as is the level of premiums which may be paid.
	Opens wide opportunity in marketing long fibres in order to strengthen recycled fibres.	Very difficult to compete in the mass market due to the establishment of the wood based industry with their large economies of scale and cost of non-wood materials generally being higher than wood.

2.4 Pulp and Paper Industry in Malaysia

The demand of paper continues to increase despite beliefs that advances in Information Technology (IT) would result in paperless global society. This is driven by the growing world population with improved income and literacy levels. At present, pulp and paper industry in ASEAN countries are relatively small in comparison to those of developed countries such as United States America, Canada and Germany.

In ASEAN countries, Malaysia, Thailand and Indonesia become the major producers of pulp and paper product. These countries have solid economic background, which has gained interest of the multinational companies to invest in these countries, hence help in nourishing the expansion of pulp and paper sectors. Meanwhile, the old manufacturing techniques in producing pulp and paper in some other ASEAN countries caused the pulp and paper sectors to be incompetitive in the international market. Figure 2.9 shows the world's paper and paperboard production in 2003. The largest producer in 2003 was United States of America followed by China, Japan, Canada and other countries. Malaysia was ranked eleventh in the list with a total of 1.3 million tonnes of pulp and paperboard production (Mustaffah, 2006).

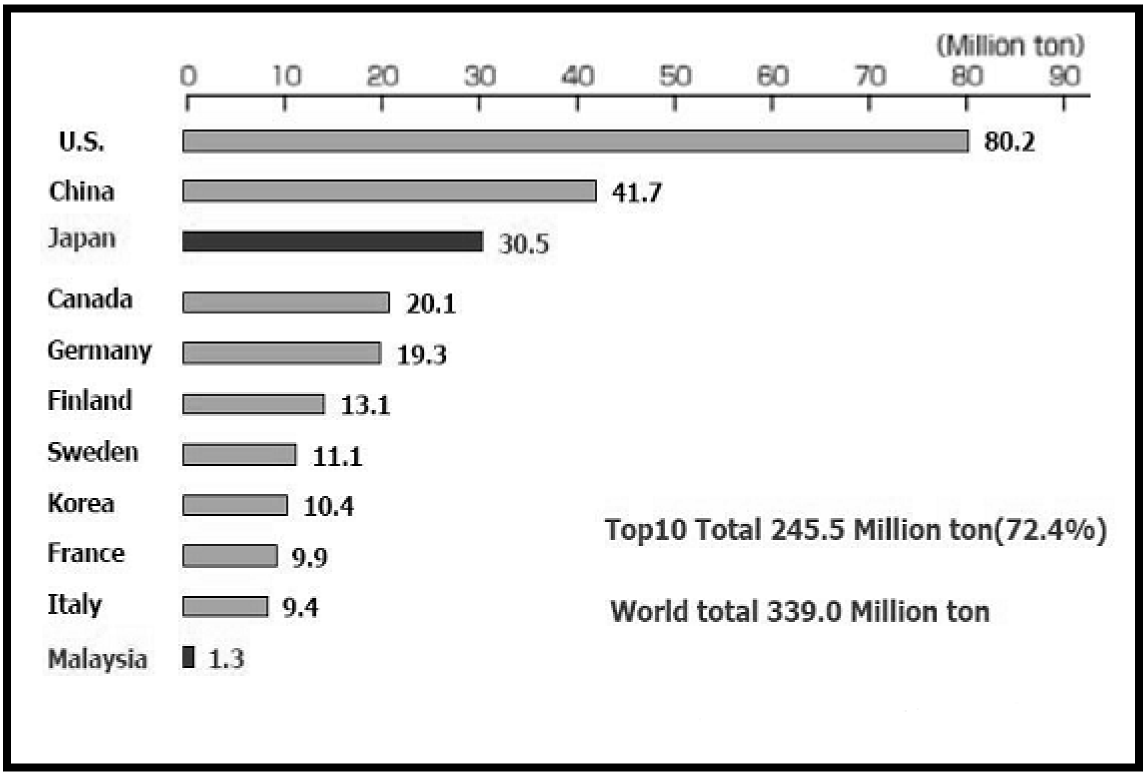

Figure 2.9 World paper and paperboard production in 2003 (Mustaffah, 2006).

At present, Malaysia has about twenty pulp and paper manufacturing companies (Figure 2.10) sustaining over one million tonnes per year of capacity pulp and paper production. The shortage of raw materials for making pulp and paper has made Malaysia a net importer of pulp, paper and paper board in order to fulfil the increasing needs of the country. Besides that, Malaysian pulp and paper industry is also heavily dependent on imported virgin pulp and striving to decrease its dependency by finding new sources of fibres. These new sources of fibres will substitute the imported virgin fibres that are mainly used to strengthen the quality of secondary fibres network in the local paper and paper-based products (Roda and Rathi, 2006).

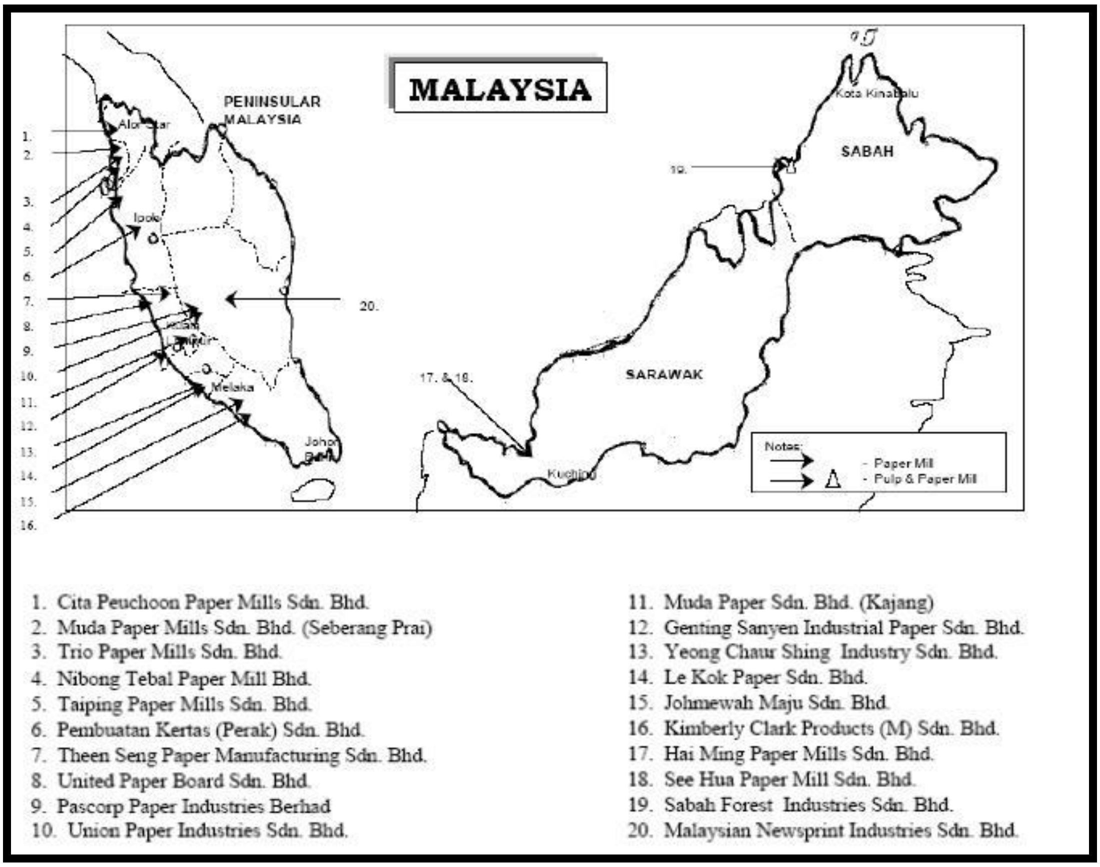

Figure 2.10 Pulp and paper manufacturers in Malaysia (Mustaffah, 2006).

Meanwhile, more forest plantation projects are planned to ensure sufficient and steady source of fibre supply in the long run. Other sources of supply are non-wood materials, such as kenaf (*Hibiscus cannabinus*) and oil palm residues which consist of empty fruit bunches (EFB), oil palm fronds (OPF) including oil palm trunk (OPT) are also presented as alternatives to wood as fibre source. The utilization of these non-wood materials is highly promoted through the emphasis of R&D and technology improvement as the use of these non-woods as raw materials can reduce the cost and help in reducing environmental problems.

Even though Malaysia is one of the major producers of pulp and paper in ASEAN countries, the country's pulp and paper industry is still too small to fulfil the domestic needs (Figure 2.11 and Figure 2.12). As a result, about half of the country requirements are imported and according to the Malaysian Pulp and Paper Association, MPPA, the industry strategy is to remain domestic-market oriented (Roda and Rathi, 2006).

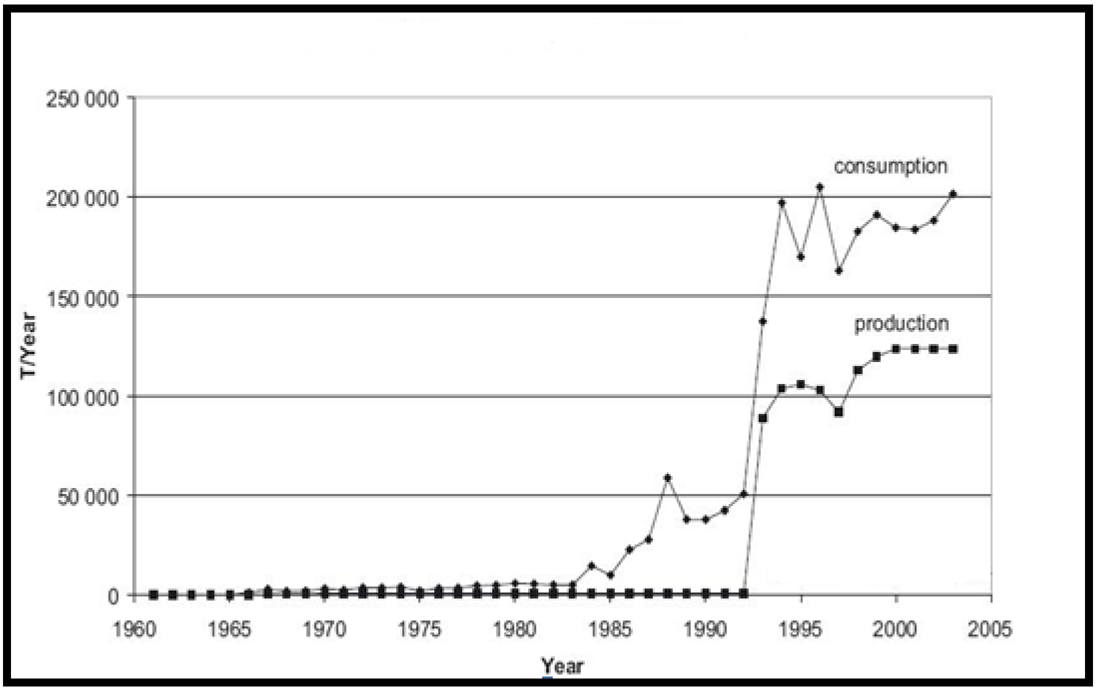

Figure 2.11 Malaysia pulp production and consumption (Roda and Rathi, 2006).

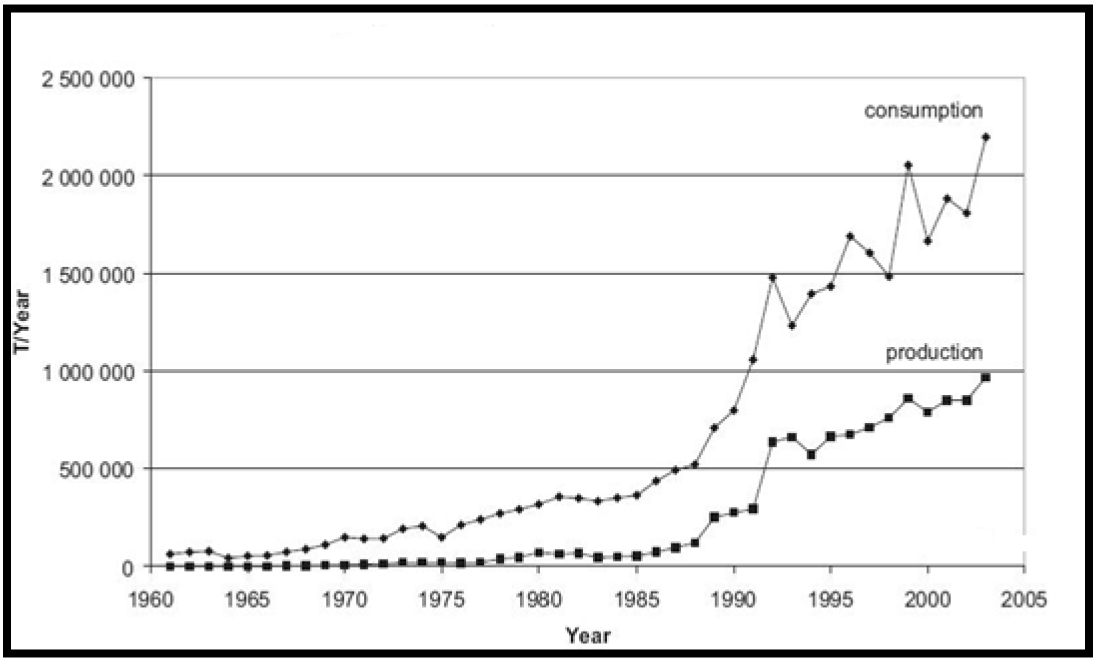

Figure 2.12 Malaysia paper production and consumption (Roda and Rathi, 2006).

2.5 Availability of Oil Palm Biomass in Malaysia

The oil palm tree or its scientific name, *Elaeis guineensis Jacq.* is the most important species in the genus *Elaeis* and a tropical plant which commonly grows in warm climates at altitude of less than 1,600 feet above sea level. The oil palm is an erect monoecious plant as it bears both male and female flowers on the same tree (Teoh, 2002).

Elaeis guineensis Jacq. belongs to the family of palms, the Arecaceae or formerly known as the Palmae. The Arecaceae are placed in the order Arecales. *Elaeis guineensis Jacq.* is grouped with *Cocos* (the coconut) and other genera in the subfamily Cocosoideae. The oil palm received its botanical name from Jacquin in 1763. The word *Elaeis* is derived from the Greek word 'elaion', which means oil while the specific name guineensis was credited to the oil palm's origin place, the Guinea coast (Corley and Tinker, 2003). The oil palm trees are shown in Figure 2.13.

Figure 2.13 Oil palm plantation (GRAIN, 2007).

Elaeis guineensis Jacq., or oil palm tree originates from tropical Africa was earliest brought to Malaysia in 1870 through the Singapore Botanical Gardens used for ornamental purposes (Mohammad Zin *et al*., 1991). Malaysia has started commercial cultivation of oil palm in 1971 and since then, Malaysia has rapidly grown to become the most mature oil palm industry the world. Growth of the industry was intense in the 1960s, resulting from the initiative of switch over from rubber to oil palm during agricultural diversification policy and used by the government as a vehicle to eradicate the poverty among the rural populace (Basiron and Weng, 2004).

From then onwards, the palm oil production started to grow rapidly from 94, 000 tonnes in 1960 to 2.6 million tonnes in 1980. As such, this first phase presented an interesting insight into approaches used by government to develop market for palm oil and this opportunity must be grabbed by the palm oil industry to take advantage of the situation and utilize the available biomass in the best possible manner (Basiron and Weng, 2004).

Besides becoming the major producer of oil palm, Malaysia is also acknowledged for its contribution in producing rubber, cocoa and coconuts. However, the preference for oil palm has led to a steady increase in oil palm replanting and the expansion of its planted areas has been greater than rubber and other crops plantations over the last four decades. The oil palm plantation areas have increased from 54, 000 hectares in 1960 to 4.05 million hectares in 2005, contributing to 10.06% of a compound annual growth (Basiron, 2007a).

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The rapid increase of oil palm plantation areas also led to the increase in oil palm production from 94, 000 tonnes in 1960 to 15 million tonnes in 2005, which is almost 160 times within 45 years. This circumstance represents a compound annual growth of 11.93% per year. This tremendous growth also signifies the country's success as world food resource (Basiron, 2007a).

As one of largest palm oil producers in the world, Malaysia is playing an important role to ensure that the yearly surplus of the exported palm oil can fulfil the growing market demand of oils and fats worldwide which is expected to rise year by year. Owing to this situation, the plantation sector must continue to be allowed to plant oil palm as long as the crop is profitable. Besides that, the performance of economies of scale derived by large private plantations and the organised smallholder sector are also greatly important and crucial to ensure that the Malaysian palm oil industry remains competitive and can contribute significantly to national productivity (Basiron, 2007b).

A lot of strategies have been taken by the government to encourage the oil palm plantation in order to ensure the operations is at an economic scale by providing an amalgamation plan through group farming, cooperatives or nucleus estates. One strategy is to encourage the organised smallholders to own 20 acres for each family instead of 10 acres at present. This strategy can provide adequate level of family income in the future and could achieve one of the government's objectives, which is to reduce the poverty among the rural populace (Basiron, 2007b).

Malaysia claims that in 1995, it was the world largest oil palm producer with 51% of world production. Table 2.2 below shows world major producers of palm oil from 2001 until 2008 where Malaysia became the largest producers of palm oil from 2001 until 2005. However, at presents, Indonesia leads the list.

Table 2.2 World Major Producers of Palm Oil, 2001-2008 (‘000 tonnes) (Kushairi and Rajanaidu, 2009)

World Major Producers of Palm Oil, 2001-2008 (‘000 tonnes)

Country	2001	2002	2003	2004	2005	2006	2007	2008
Indonesia	8, 080	9, 370	10, 600	12, 380	14, 100	16, 050	17, 270	19, 330
Malaysia	**11, 804**	**11, 909**	**13, 355**	**13, 976**	**14, 962**	**15, 881**	**15, 824**	**17, 734**
Thailand	625	600	690	735	700	860	1, 020	1, 170
Nigeria	770	775	785	790	800	815	835	860
Colombia	548	528	527	632	661	713	732	800
Ecuador	228	238	262	279	319	352	396	415
PNG	329	316	326	345	310	365	384	400
Cote d’lvoire	205	265	240	270	320	330	320	330
Honduras	130	126	158	170	180	195	220	268
Brazil	110	118	129	142	160	170	190	220
Costa Rica	150	128	155	180	210	198	200	202
Guatemala	70	86	85	87	92	125	130	139
Venezuela	52	55	41	61	63	65	70	56
Others	883	895	906	940	969	1, 023	1, 083	1, 194
Total	**23, 984**	**25, 409**	**28, 259**	**30, 987**	**33, 846**	**37, 142**	**38, 674**	**43, 118**

Beside palm oil, the oil palm sector is a prolific producer of biomass or fibre products and these are available regularly throughout the year from the palm oil milling sector in Malaysia. According to Ariffin *et al*. (2009), the palm oil milling in Malaysia generates more than 100 millions of metric tonnes of renewable oil palm wastes annually consisting of empty fruit bunches (EFB) , oil palm fronds (OPF) and oil palm trunks (OPT). During replanting, large quantities of EFB, OPF and OPT are made available and these abundant renewable sources are presently used for developing value-added products such as wood composite product, medium density fibreboard (MDF), plywood or pulp (Basiron, 2007b).

Agricultural wastes especially from oil palm trees are rich in celluloses and hemicelluloses. In the research, the cellulose and hemicelluloses content are critical for paper making as it is directly proportional to the pulp mechanical strength. Besides that, these palm fibres also have excellent physical and mechanical properties, which make these renewable sources suitable for producing composites for various end uses such as moulded particleboard, fibre-filled thermoplastic, thermoset composites and moulded paper products (FIDEC, 2010).

Research by Rozman *et al*. (2004) also shows that the utilization of these by-products can offer several advantages such as greater deformability and biodegradability which is very useful in papermaking process. Besides that, the use of these lignocellulosic fibres would help reduce the cost of waste disposal and if these renewable by-products are fully exploited, the oil palm industry can easily widen its revenue, hence, generate base to become more competitive. Table 2.3 below shows the availability of oil palm biomass from year 2004 until year 2020 in Malaysia.

Table 2.3 Projection of Oil Palm Biomass Availability in Malaysia (tonnes/year) (Salim *et al*., 2007)

Year	**2004-2006**	**2007-2010**	**2011-2013**	**2014-2016**	**2017-2020**
Oil palm trunk (OPT)					
Amount of fibre bundles	2,166,178	1,742,360	2,307,450	1,930,724	1,601,088
Amount of parenchyma	1,273	1,024,599	1,356,902	1,135,367	941,524
Amount of bark	580,848	467,204	618,730	517,713	429,323
Amount of the whole trunk	4,020,852	3,234	4,283,082	358,803	2,971,934
Oil palm fronds (OPF)					
Amount of leaf stalks	13,421,645	13,163,181	12,997,026	13,458,568	13,643,185
Amount of petiole	7,025,525	6,890,233	6,803,260	7,044,853	7,141,490
Empty fruit bunches (EFB)					
Amount of bunch stalks	626,175	618,184	619,637	636,345	626,901
Amount of spikelets	2,234,019	2,205,511	2,210,694	2,270,303	2,236,611
Amount of the whole EFB	2,860,194	2,823,695	2,830,331	2,906,647	2,863,512