MEDIUM-DENSITY FIBREBOARD (MDF) FROM OIL-PALM FRONDS

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Thesis submitted in partial fulfillment of the requirements for the award of the degree of
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ABSTRACT

Malaysia is one of the top five exporters of Medium-density Fibreboard (MDF) in the world in which total production capacity exceeds one million cubic metres per year. Most of MDF producers use rubberwood as their main raw material for manufactured products. Resulted from this, there was insufficient supply due to high demand particularly from the panel composite sector. The unsecure supply and price hike of rubberwood has led MDF industries to look for alternative raw material. Oil palm fronds (OPF) are readily available residues from palm oil industry and have tremendous potential to be used as fibre raw material in Malaysia. In this study, the manufacturing of MDF from oil palm fronds (OPF) was studied and characterized in order to measure the compatibility with MDF using rubberwood sources. The results proved that MDF produced from 100% OPF and its mixture offer good physical and mechanical properties. Although it gives high value for thickness swelling, the value is still acceptable with the commercialize standard. MDF from OPF also has sound absorption qualities that were generally superior at several frequencies compared to commercialize fibreboards samples. In other aspect of economic feasibility analysis, it was observed that MDF from oil palm fronds offering strategically lower price than other competitors product since it using low cost raw material. It also can gain niche in the market area due to the affordable price and will be able to generate highly predictable cash flows on a monthly basis from the manufacturing and distribution of the products. In conclusion, oil palm fronds can be a suitable alternative raw material in replacing the rubberwood sources for MDF production and very feasible to be manufactured in Malaysia.

ABSTRAK

Malaysia merupakan salah satu daripada lima pengeksport terbesar Medium-density Fibreboard (MDF) di dunia di mana jumlah kapasiti pengeluaran melebihi satu juta meter padu setahun. Kebanyakan pengilang MDF menggunakan kayu getah sebagai bahan mentah utama untuk penghasilan produk mereka. Berikutan daripada permintaan yang tinggi terutamanya daripada sektor komposit panel, bekalan kayu getah adalah sangat terhad. Kenaikan harga getah telah membawa industri MDF untuk mencari alternatif bahan mentah kepada kayu getah. Pelepah kelapa sawit merupakan sisa sedia ada daripada industri kelapa sawit dan mempunyai potensi yang besar untuk digunakan sebagai bahan serat mentah di Malaysia. Di dalam kajian ini, pembuatan MDF dari pelepah kelapa sawit telah dikaji dan dicirikan untuk mengukur perbandingannya dengan MDF dari sumber kayu getah. Berdasarkan keputusan yang diperolehi, ianya terbukti bahawa MDF yang dihasilkan dari 100% pelepah kelapa sawit dan campurannya menghasilkan cirri-ciri fizikal dan mekanikal yang baik. Walaupun ia menunjukkan nilai yang tinggi bagi ciri ketebalan pengembangan dengan air, nilai ini masih di dalam lingkungan had standard yang telah ditetapkan. MDF dari pelepah kelapa sawit juga mempunyai ciri-ciri penyerapan bunyi yang secara amnya baik pada beberapa frekuensi berbanding dengan papan gentian sampel yang telah dikormesilkan. Di dalam aspek ekonomi analisis, ianya telah diperhatikan bahawa MDF dari pelepah kelapa sawit mampu menawarkan harga yang lebih rendah daripada pesaing MDF yang lain kerana ia menggunakan kos bahan mentah yang rendah. Ia juga mampu mendapat kelompok pasaran yang tinggi kerana harganya yang berpatutan dan akan dapat menjana aliran tunai bulanan yang sangat tinggi hasil dari pembuatan dan penjualan produk tersebut. Secara kesimpulannya, pelepah kelapa sawit boleh dijadikan sebagai bahan mentah alternatif yang sesuai sebagai penggantian kepada sumber kayu getah untuk pengeluaran MDF di Malaysia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

%	Percentage
<	Less than
≤	Less than and equal to
≥	Greater than and equal to
α	Alpha
t	Tonne
hr	Hour
mm	Millimeter
m^3	Meter cube
km	Kilometer
kg/m^3	Kilogram per meter cube
N/mm^2	Newton per millimeter square
$g.cm^{-3}$	Gram per centimeter cube
Hz	Hertz
RM	Ringgit Malaysia
$	Dollar sign

LIST OF ABBREVIATIONS

ANSI	*American national standards institute*
ASTM	*American society for testing and materials*
CO	Carbon monoxide
CO_2	Carbon dioxide
DBEP	*Discounted break-even period*
DPBP	*Discounted payback period*
EFB	Empty fruit bunch
EN	European standard
HB	Hard boards
HDF	High-density fibreboards
HSE	Health, safety and executive
IB	Internal bonding
LDF	Low-density fibreboards
MC	Moisture content
MD	Medium boards
MDF	Medium-density fibreboards
MELs	Maximum exposure limits
MOE	Modulus of elasticity
MOR	Modulus of rupture
NPV	*Net present value*
OPF	Oil palm fronds
OPT	Oil palm trunk
PM	Particulate matter
PBP	*Payback period*
TS	Thickness swelling
UF	Urea-formaldehyde
VOCs	Volatile organic compounds
WESPs	Wet Electrostatic Precipitators

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Malaysia is amongst the world's top producers of palm oil with the current planted area is expanding to around 4.0 million hectares. Success of palm oil industry in Malaysia is from the influence of government and private sector strategies and policies. Thus, the explosive expansion of oil-palm plantations in this country has generated enormous amounts of agricultural waste which created problems in replanting, and raised significant environmental concerns. In Malaysia alone during the recent past year, produced about 30 million tonnes of oil-palm biomass, including trunks, fronds, and empty fruit bunches (Anon, 1991).

Recently, Oil palm fronds (OPF) has been investigated as a raw material for building materials, solid fuel pellets, chemical products, particleboard, fibreboard, blackboard as well as pulp and paper (Kobayashi et al., 1985). Although fibreboard can be produced from any lignocellulosic material, very little is known about using OPF for it.

Lately, Medium-density Fibreboard (MDF) production in Malaysia has become skyrocketed since the global demand for MDF is increasing rapidly. Malaysia now has eight MDF mills, mostly depend on the supply of rubberwood as their feedstock. Projections show that in the near future the supply of rubberwood will not meet the demand for making MDF. With the declining supply of rubberwood, the Malaysian MDF industry has to search for a new fibre sources in order to sustain their operations in future.

The biggest alternative is replacing the rubberwood sources with OPF which is readily available throughout the year and constant supply for MDF manufacture. Furthermore this green fibre source is environment friendly and would help to reduce source from wood supply.

1.2 PROBLEM STATEMENT

Within three decades, the Medium-density Fibreboard (MDF) industry has grown and contributed significantly to the external trade of the wood-based sector of Malaysia. However, at present, the industry is at a cross road. Although in Peninsular Malaysia MDF trade is expanding, but initial relative advantages over other competitors have marginally eroded. The strong economic growth and high demand for MDF in Asia has contributed to increased usage of wood-based raw materials especially the rubberwood.

Due to a drastic fall in forest resource, the diversification of the raw materials used has become a great interest. Moreover, the increasing environmental awareness and concerns of the health of forests, wildlife diversity, biomass productivity, climate, and the biological sink directs research to alternative fibre recourses. The biggest alternative is replacing the rubberwood supply with agricultural residues (Guntekin et al., 2008) such as OPF which is particularly important natural resource in the wood-based industries. This natural fibre possesses low density, low production costs, easy processing, light weight and low abrasiveness to equipment (Hill and Abdul Khalil, 2000) which is suitable for Medium-density Fibreboard (MDF) production.

1.3 OBJECTIVE OF STUDY

1) Investigate the manufacturing of Medium-density Fibreboard (MDF) from Oil Palm Fronds (OPF) and characterising it in comparison with the Medium-density Fibreboard (MDF) produced from rubberwood sources.

2) Carry out a feasibility analysis of marketing in order to establish Medium-density Fibreboard (MDF) produced from Oil Palm Fronds (OPF) production facility in Malaysia.

1.4 SCOPE OF STUDY

In order to achieve the objective, the following scopes have been identified:

- Investigation of the MDF production process, resource availability and pricing from mill residue and roundwood, utility consumption, hazard assessment and management, standard regulation followed, capital costs associated with production, estimates of operating costs, revenue estimates and calculation of return on investment.

1.5 RATIONALE AND SIGNIFICANCE

This research was part of a larger effort in order to commercialize Medium-density Fibreboard (MDF) from Oil Palm Fronds (OPF). The interest in the substitution of rubberwood resources with cost-effective raw material for the MDF manufacturing has greatly increased due to the environmental awareness and concerns of the health of forests. From this research, basically, it helps to establish and provide new business opportunity for this type of MDF since it is preferable in economic feasibility and user friendly concept.

CHAPTER 2

LITERATURE REVIEW

2.1 MEDIUM-DENSITY FIBERBOARD (MDF)

Medium-density Fibreboard (MDF) is an engineered wood product formed by breaking down hardwood or softwood residuals into wood fibres bonded with a synthetic resin which is usually formaldehyde-based. It forms into panels by applying high temperature and pressure. Although it has been commercially available since the 1960s, its use has become significant only in the last decade or so.

MDF is denser than plywood. It is made up of separated fibres, but can be used as a building material similar in application to plywood. It is also stronger and much denser than normal particle board. Originally, the methods of manufacture of wood-based fibreboard are generally divided into the wet process fiberboards (fibre distribution in water) and dry process methods (fibre distribution in air).

Wet process boards are fibreboards having fibre moisture content (MC) of more than 20% at the stage of forming. Wet process hardboards use water as the distribution medium for the fibres to be formed into a mat. Additionally, wet process boards are classified according to density, as follows:

- Hard boards (HB): Boards with a density $\geq$ 900 kg/m^3
- Medium boards (MD): Boards with a density $\geq$ 400 kg/m^3 to $<$ 900 kg/m^3

Dry process fibreboards having a fibre moisture content of less than 20% at the stage of forming, and having a density ≥ 450 kg/m^3. These boards are essentially produced under heat and pressure with the addition of a synthetic adhesive. For marketing purposes, MDF of specific density range can be given different denominations. For example, the following density-related marketing terms for MDF have become established:

- HDF: MDF with a density ≥ 800 kg/m3
- Light MDF: MDF with a density ≤ 650 kg/m3
- Ultra-light MDF: MDF with a density ≤ 550 kg/m3

2.1.1 Application of Medium-Density Fibreboard (MDF)

MDF can be used for a variety of application because of its smooth characteristic and uniform consistency. It also will not warp which makes it an ideal choice for cabinetry and molding projects. The MDF is often used in place of plank wood, particleboard or high density fiberboard because when sawed it produces a fine even edge. Because of how smooth the surface is, it takes well to painting and only needs a primer and two coats of paint to have an attractive finish unlike some other wood products that may require more sanding and additional coats of paint. Because it does not warp, it is also used quite a bit in bathrooms for cabinets or in other high humidity applications.

Home builders, cabinet makers and carpenters use medium density fiberboard for furniture, shelving, flooring, molding and doors. The wood is very versatile and can be used for a number of applications. It is used often for doors because it insulates sound and heat very well. Taken in conjunction with its smooth surface and ability to take paint well, it is an ideal material for doors. The wood is also very flexible in the type of treatments that it can take such as nailing, gluing, screwing or stapling. The only drawback to medium density fiberboard is the resin that is used to strengthen the wood. This resin contains formaldehyde so care should be taken when cutting it to reduce the amount of dust that is airborne. Try to reduce exposure to MDF whenever possible.

When medium density fiberboard is used for cabinets and other wood working projects, it is very often covered in a veneer or laminate of real wood to disguise the MDF, especially along edges that may be visible. MDF is also a great wood to use for those who are environmentally conscious. Because it is made from scraps and other waste products it is friendlier to the environment. Instead of these items going to a land fill they are recycled. Figure 2.1 below shows general diversity of applications for MDF.

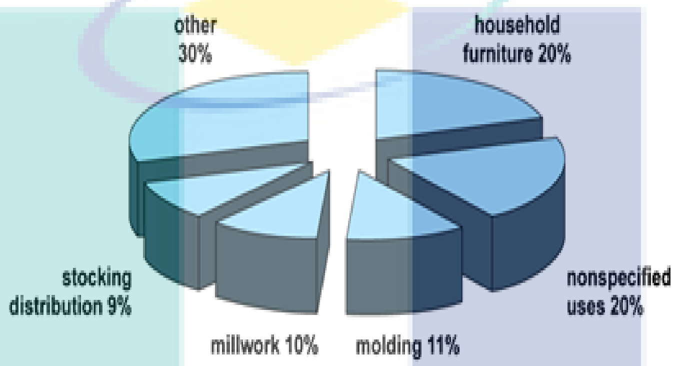

Figure 2.1: Uses of Medium-density Fibreboard

2.2 MARKET DEMAND

Medium density fiberboard (MDF) is very versatile and can be used for a number of applications, it is used often because it insulates sound and heat very well and ability to take paint well. The wood is also very flexible in the type of treatments that it can take such as nailing, gluing, screwing or stapling. Based on its diversity of application, the majority of target customers will be home builders, contractors, furniture manufacturers, cabinet makers and carpenters. Target market profile will be middle income families that are both starting their careers and families and those that have been established and are looking to use good quality MDF at lower price especially in construction and furniture industry.

The global market outlook for Medium-density Fibreboard (MDF) is favourable. Growing environmental concerns are also leading to more MDF usage. MDF is becoming a popular alternative to plywood and solid wood as it is cheaper and more eco-friendly. Generally, MDF prices are at 30-50% the prices of other wood products. The global demand for wood products is also correlated with population and economic growth. As the world population projected to increase by 6% between 2005 and 2012, mainly from the fast-growing population in Asia, demand for furniture & fixtures and household products are also set to increase. In addition, steady world economic growth forecasted in 2012, would further continue to drive demand of MDF.

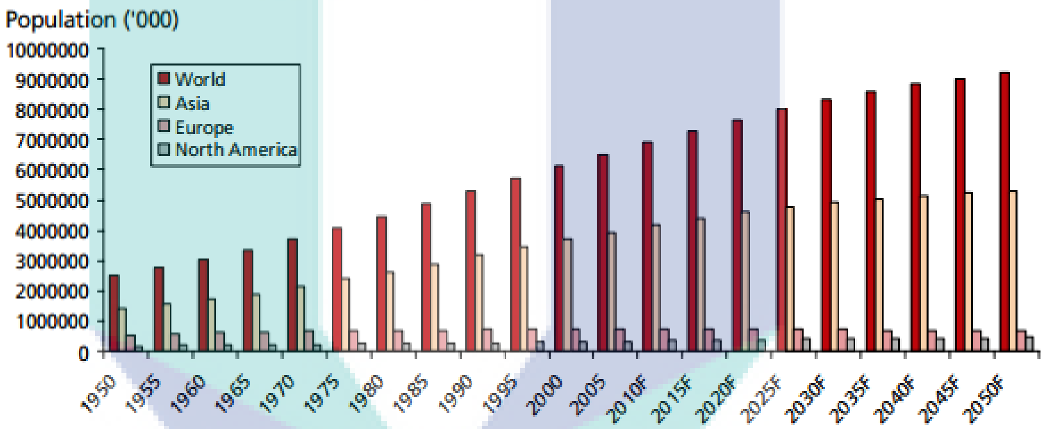

Figure 2.2: The global demand for wood products is supported by population growth

Source: E. Pepke, 2002

Malaysia is the key beneficiary as it is currently the 3rd largest MDF exporter in the world mainly to Japan, China, UAE, Vietnam and Pakistan. In addition, Malaysia's furniture exports are projected to grow by 7-9% every year, signalling continued strong external demand for wood-based products. Wooden furniture accounts the largest with 80% of the total exports. Initiatives from the government to promote local furniture would also further boost exports. For instance, the Malaysian International Furniture Fair held every year had generated 30% out of total furniture export sales. Figure 2.3 shows furniture exports in Malaysia. The mainline application of MDF is furniture making up about 65% of the market whereas construction and finishing materials account for 35%. 10-30 mm thick MDF panels enjoy the greatest demand in the global market as they successfully replace wood in furniture, joinery and building goods production. The principal requirement for the board quality is its being deep-milled and treated/finished in many ways (painted, varnished, veneered and laminated). The main MDF panel consumers are manufacturers of modular furniture, furniture facades, furniture, interior doors, wall panels and flooring.

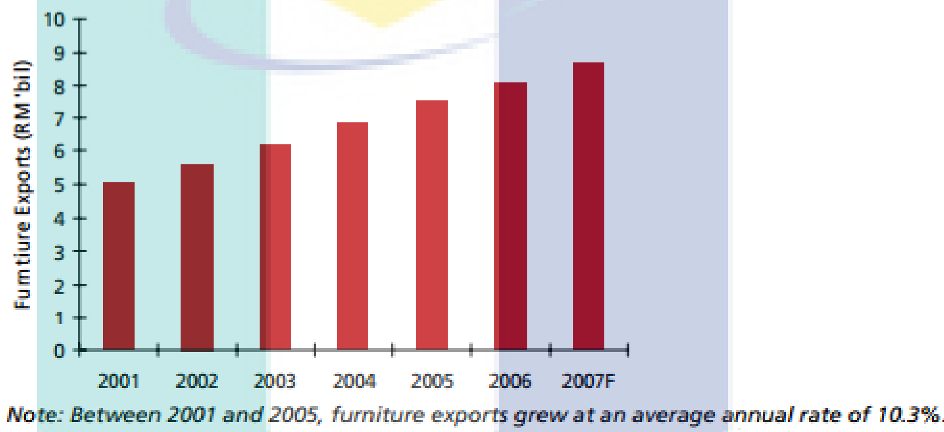

Figure 2.3: Malaysia's furniture exports are projected to grow by 7-9%

The MDF market is developing throughout the world and its annual growth makes up about 15% per year. The MDF share in the total production of wood-based panels is approximately 20%. The world trends in MDF production are as follows

- Production capacity increase to 250-300 m^3/year
- Increase in demand for MDF panels over 30 mm thick as a substitute for solid wood
- Interest to LDF panels with a density of 600–650 kg/m^3 that can compete with particle board

- Development of new MDF panels (penetration coating, electrostatic-resistant panels for office furniture, honeycombed panels, panels with "slot-mortise" profiling, etc)
- Implementation of technologies allowing MDF production from cheap available raw wood in countries with scarce forest resources
- Expansion of MDF application in joinery production.

According to analysts, the MDF market is sure to grow and expand. Increasing number of furniture manufactures buying MDF finishing equipment because they are switching from particle board to MDF. The advantages of MDF have been recognized such as easy to mill, higher density, excellent surface quality and ecological safety. Lacking in defects typical of natural wood (knots, voids, wind-checks, splits) make the demand for MDF is growing for the production of building and finishing materials and joinery. For MDF manufacturers themselves a developed regional dealership network is assuming a great importance as furniture production tends to shift to the regions and a share of small businesses in the consolidated production is (18-19%) besides high quality and beneficial price, competitiveness factors include security of supply, a wide range of goods and service. Figure 2.4 shows the wood based panel consumption throughout the world including the consumption of MDF.

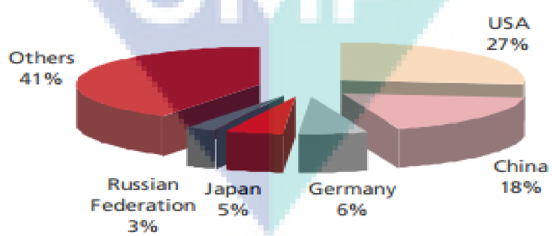

Figure 2.4: Wood-based Panel Consumption

2.3 MEDIUM-DENSITY FIBREBOARD (MDF) PRICING

Majority of Malaysia's global competitive advantage lies in its rubberwood processing industry, which has made it the centre and model for the processing and utilization of rubberwood worldwide. Ironically, Malaysia's total acreage of rubber plantation declined from 8,636 m^3 in 1998 to 4,939 m^3 in 2004, and according to the study in table 2.1 below, the supply of rubberwood is projected to start falling back from 2008.

Table 2.1: Projected total wood production from rubber plantations in Peninsular Malaysia from 1996-2012

Year	Estates (000 m^3)	Smallholdings (000 m^3)	Total (000 m^3)
1996	2,899	4,208	7,107
1998	1,951	6,685	8,636
2000	2,683	6,062	8,745
2002	1,847	4,961	6,808
2004	1,488	3,451	4,939
2006	1,431	5,157	6,588
2008	1,720	7,261	8,981
2010	1,334	4,748	6,082
2012	581	2,626	3,207

Source: Arshad et al., 1996

From this situation, natural rubber prices have corrected sharply from their peak. Since 2002, prices have been driven up by strong global demand (for items such as automotive tyres, rubber gloves, etc.) against a limited supply, since newly planted rubber trees require five to seven years before they can start yielding latex. The price of synthetic rubber (oil-based), a substitute, has also been rising in line with crude oil prices. The increase in the value of natural rubber, in turn, has delayed the felling of rubber trees and raised the price of rubberwood logs in tandem. Figure 2.5 shows the increasing prices of rubberwood logs.

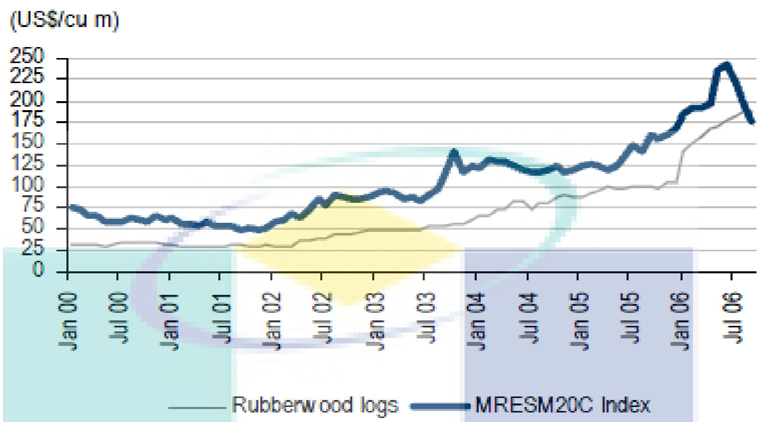

Figure 2.5: Surging rubberwood log cost peaking

Source: International Tropical Timber Organisation

Selling prices of MDF are determined globally by demand and supply. In the figure 2.6, it has only been in 2006 that MDF price has started rising. Rising costs appear due to the increasing costs of its main raw material, the rubberwood logs. Surging rubberwood logs prices are pulling up MDF prices, just as raw material costs appear to have peaked. So, in order to gain more control over the raw material supply, other alternatives such as agriculture residues (e.g. Oil Palm Biomass) can be considered as a substitution for rubberwood logs. By using these alternatives for raw materials, it will help to reduce usage of rubberwood as well as lower the MDF prices.

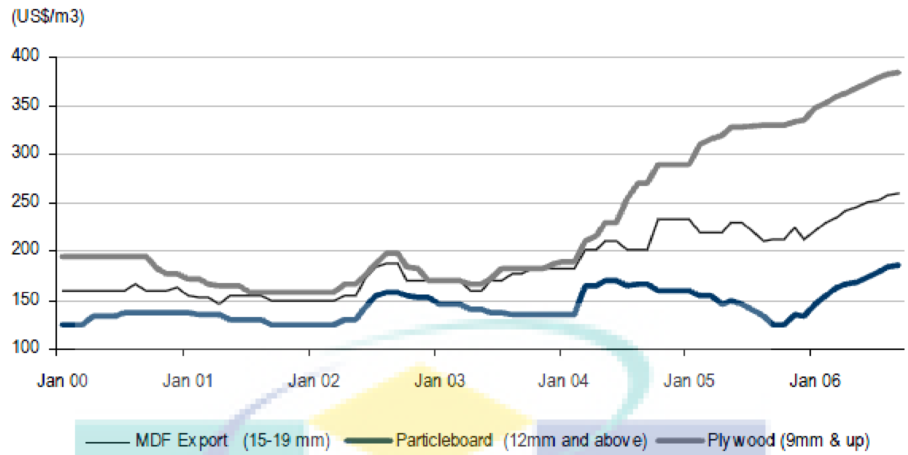

Figure 2.6: MDF, particleboard and plywood prices

Source: International Tropical Timber Organisation

2.4 OIL PALM FRONDS

2.4.1 Availability of Oil Palm Fronds

The average economic life-span of the oil palm is 25 years. A marked increase in the cultivation of oil palm began in 1960 (Kamaruddin et al. 1991), so that the year 1990 onwards will see a peak in replanting. Oil Palm Fronds (OPF) are collected during pruning and replanting activities. In Malaysia, the availability of fronds during these activities were calculated using an estimate of 10.4 tonnes hr^{-1}, which currently gives an average of 6.97 million tonnes per year. Meanwhile, it was estimated at an average of 54.43 million tonnes per year of oil palm fronds will be available during the replanting process in the years of 2007 – 2020. This will be a good opportunity to harness the ligno-cellulosic biomass or by-products of the oil palm fronds.

2.4.2 Processing and Utilization of Oil-Palm Fronds

At present, oil palm fronds are not only underutilized but frequently the causes of pollution as well (Husin et al., 1985). In practice this biomass is burned in incinerators by palm oil mills which not only creates environmental pollution problems in nearby localities but also it offers limited value to the industry. The sheer volumes of oil palm fronds and their environmental friendliness cry for their use in economic products. Currently, oil palm fronds are left rotting between the rows of palm trees, mainly for soil conservation, erosion control, as organic fertiliser and ultimately the long-term benefit of nutrient recycling.

The large quantities of fronds produced by a plantation each year also make these a very promising source of roughage feed for ruminants. The suitability of oil palm fronds as a roughage source was determined by the chemical analysis and metabolizable energy (ME) value (Table 2.2) of the oil palm fronds itself (Alimon and Hair Bejo 1995). The petiole and leaflets of oil-palm fronds are chopped into lengths of about 2 cm and utilized as cattle feed either green, or conserved as silage in combination with other ingredients as total mixed rations (A. Hassan et al., 1991).

A digestibility study conducted using mature Kedah-Kelantan bulls (A. Hassan et al., 1992) indicated a dry matter digestibility value of about 45% for oil palm frond silage. This encouraging result was further tested for the suitability of oil palm fronds in long-term feeding/production trials on beef cattle (growing and finishing), and also on lactating dairy cows.

Table 2.2: Chemical composition (% dry matter) and nutritive values of oil palm fronds and other oil-palm by-products

By-products	CP	CF	NDF	ADF	EE	ASH	ME(MJ/kg)
Palm kernel cake	17.2	17.1	74.3	52.9	1.5	4.3	11.13
Palm oil mill effluent	12.5	20.1	63.0	51.8	11.7	19.5	8.37
Palm press fiber	5.4	41.2	84.5	69.3	3.5	5.3	4.21
Oil-palm fronds	4.7	38.5	78.7	55.6	2.1	3.2	5.65
Oil-palm trunks	2.8	37.6	79.8	52.4	1.1	2.8	5.95
Empty fruit bunches	3.7	48.8	81.8	61.6	3.2	-	-

Source: Alimon and Hair Bejo 1995

2.4.3 Characteristics of Oil Palm Fronds (OPF)

An analysis done showed that OPF fibre characteristics are better compared to those of the Oil Palm Trunk (OPT) and Empty Fruit Bunch (EFB), which contain unwanted elements such as parenchyma and residual oil that are detrimental to the strength properties of the boards produced from them. Oil palm fronds (OPF) contains quite significant amount of organic nutrient, which contributes to its fertilizer values (Table 2.3). Bioconversion of lingo cellulosic waste materials to chemicals and fuels are receiving interest as they are low cost, renewable and widespread in nature.

Table 2.3: Nutrient composition of oil palm fronds

Oil Palm Fronds	Dry matters (ton/hectare)	Nutrient (kg/hectare)			
		N	P	K	Mg
Replanting	14.4	150.1	13.9	193.9	24.0
Pruning	10.4	5.4	10.0	139.4	17.2

OPF consists primarily of celluloses, hemicelluloses and lignin, and lesser amounts of protein, oil and ash that make up the remaining fraction of the lignocelluloses biomass

(Sjostrom, 1981), which are more or less comparable with that of other wood or lignocellulosic materials (Table 2.4). The toughness of the native cellulose fibre results because it is embedded in lignin. The hemicelluloses provide the link between lignin and cellulose. This makes the oil palm fronds is suitable as a raw material for the production of wood-based product.

Table 2.4: Proximate analysis of biomass of oil palm fronds (%, dry weight)

Lignin	18.3
Hemicellulose	33.9
α-cellulose	46.6
Holocellulose	80.5
Ash	2.5
Alcohol-benzene solubility	5.0

2.5 MDF INDUSTRY DESCRIPTION IN MALAYSIA

The development of MDF industry in Malaysia started in 1987 but has since rapidly developed to eight plants, seven of which is in the peninsula. The production, consumption, export and import status of MDF in Malaysia is provided in Table 2.5. Most plants used rubberwood as their major raw material. Projections show that in the near future the supply of rubberwood will not meet the demand by MDF plants. One of the possibilities in overcoming this problem is to embark an intensive forest plantation program. Effective utilisation of fast-growing non-wood lignocelluloses materials and agro-wastes has been of great interest due to a drastic fall in forest resource. Resulted from this, MDF made from oil palm fibres have been widely studied and developed.

Table 2.5: Production, consumption, export and import status of MDF in Malaysia (000 m^3)

Year/Item	1995	2000	2005	2010*
Production	350	1 000	1 500	2 000
Consumption	100	180	290	417
Export	250	820	1 210	1 583
Import	0	0	0	0

Sorce: M. Shahwahid and A. Rahim (2008)

2.5.1 Current and Future Trends

The fiberboard industry as a whole is a fairly stable industry, with future trends indicating increasing growth. Medium-density Fiberboards (MDF) from oil-palm fronds are still relatively new in Malaysia and other countries. Since Malaysia is the third-largest exporter of Medium-density Fibreboard (MDF) in the world, this offers market opportunity and a lot of room for industry growth in this area. Future trends show a demand for this type of manufacturing/ retail operations. Figure 2.7 shows Malaysia as a major MDF exporter in the world.

Figure 2.7: Malaysia is a major MDF exporter in the world

CHAPTER 3

METHODOLOGY

3.1 MANUFACTURING OF MEDIUM-DENSITY FIBREBOARD FROM OIL PALM FRONDS

Manufacturing of MDF from OPF using the same processing steps as those of conventional MDF, starting from chipping, refining, glue dosing, drying, mat forming to hot pressing. The length of oil palm fronds generally in the range of 0.5 - 2.0 m depending on species, while the wood-based raw materials are at least 10 times larger in size. Due to this factor, the manufacturing process differs principally at the beginning. Commercial production of oil palm fronds MDF in full-scale mills still does not exist today. However, several pilot-plants for production of laboratory oil palm fronds MDF are available. Figure 3.1, 3.2 and 3.3 illustrate the process flow on the manufacture of MDF from OPF.

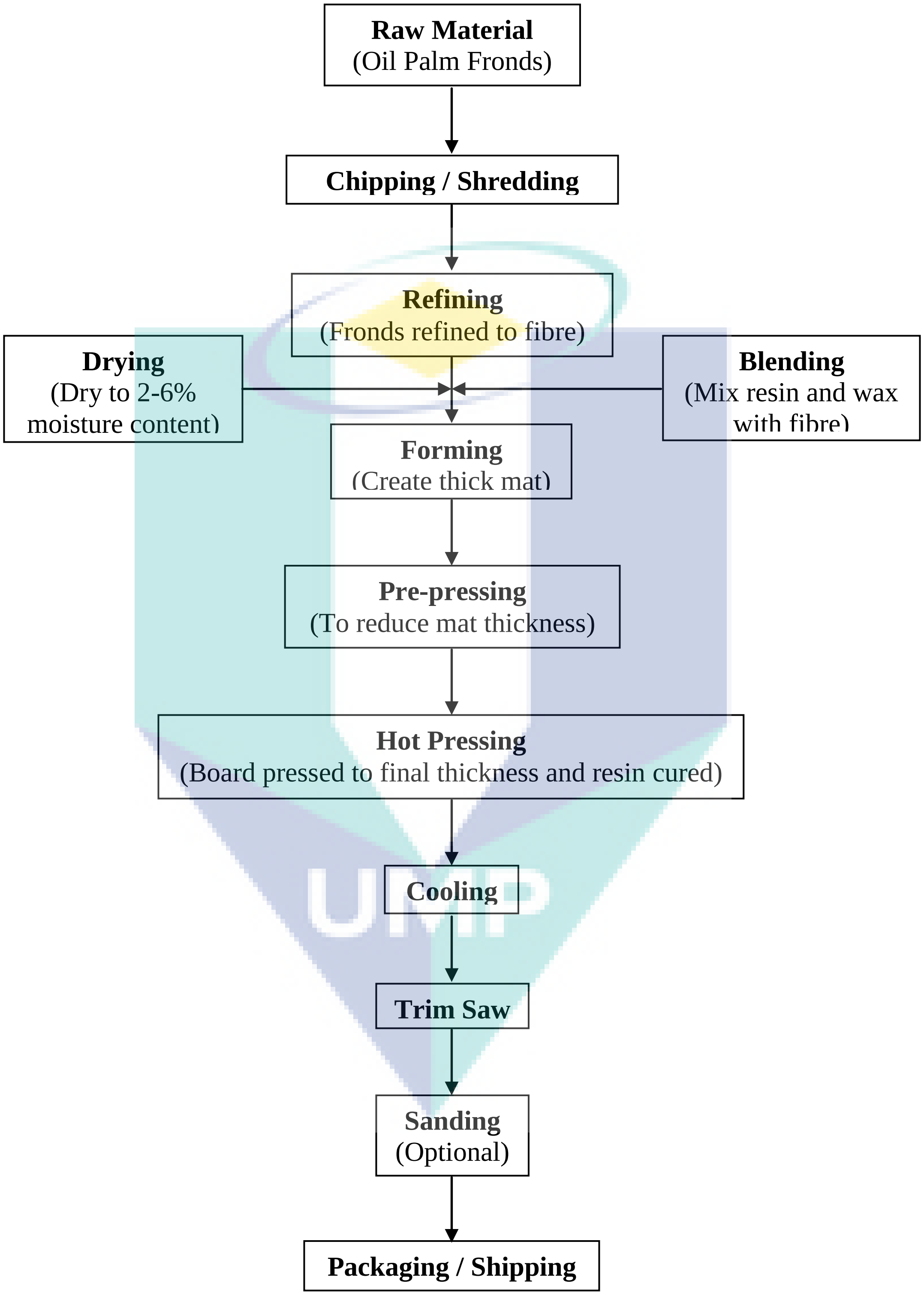

Figure 3.1: Block diagram of MDF manufacturing from oil palm fronds

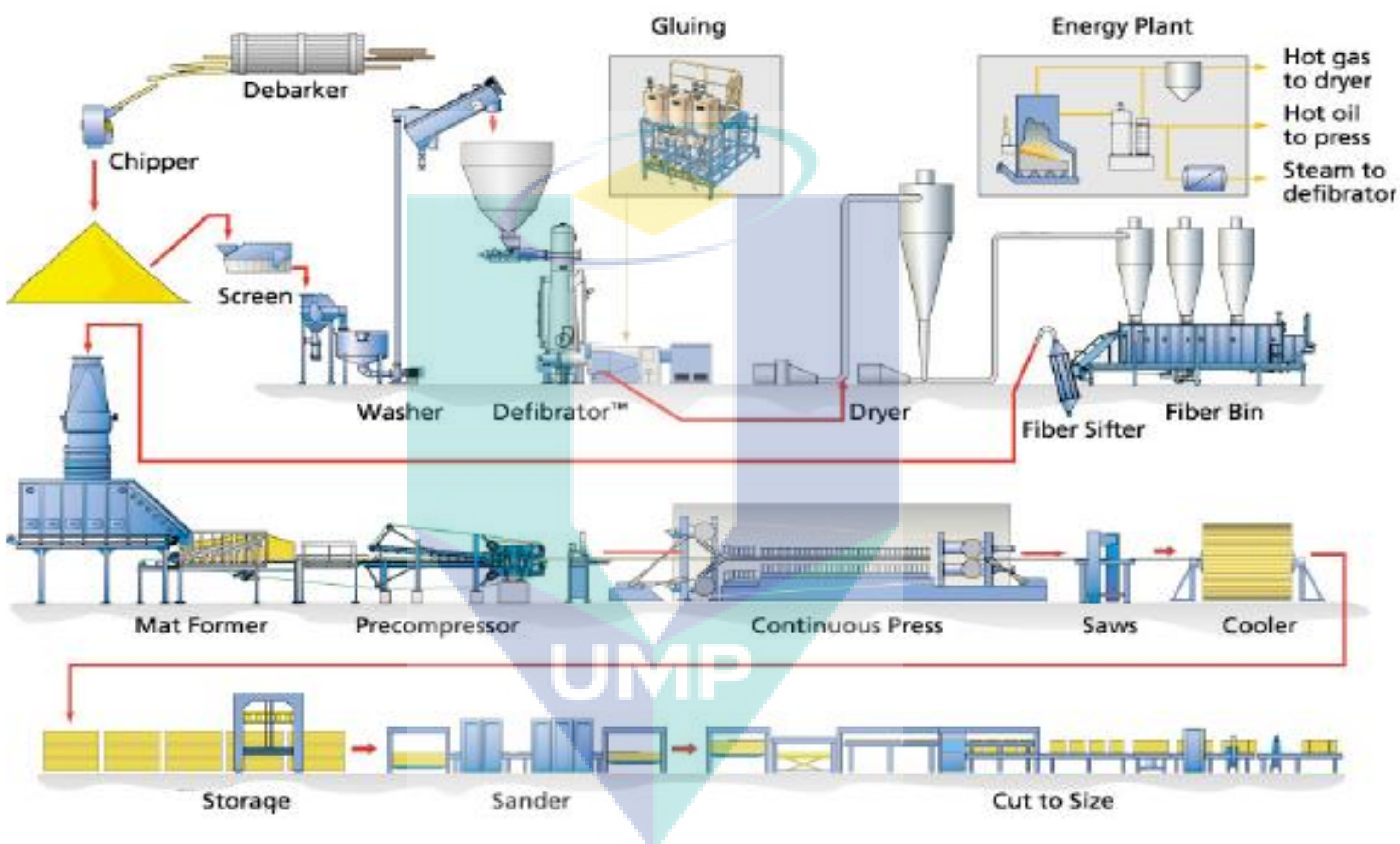

Figure 3.2: Typical process operations in the manufacture of MDF

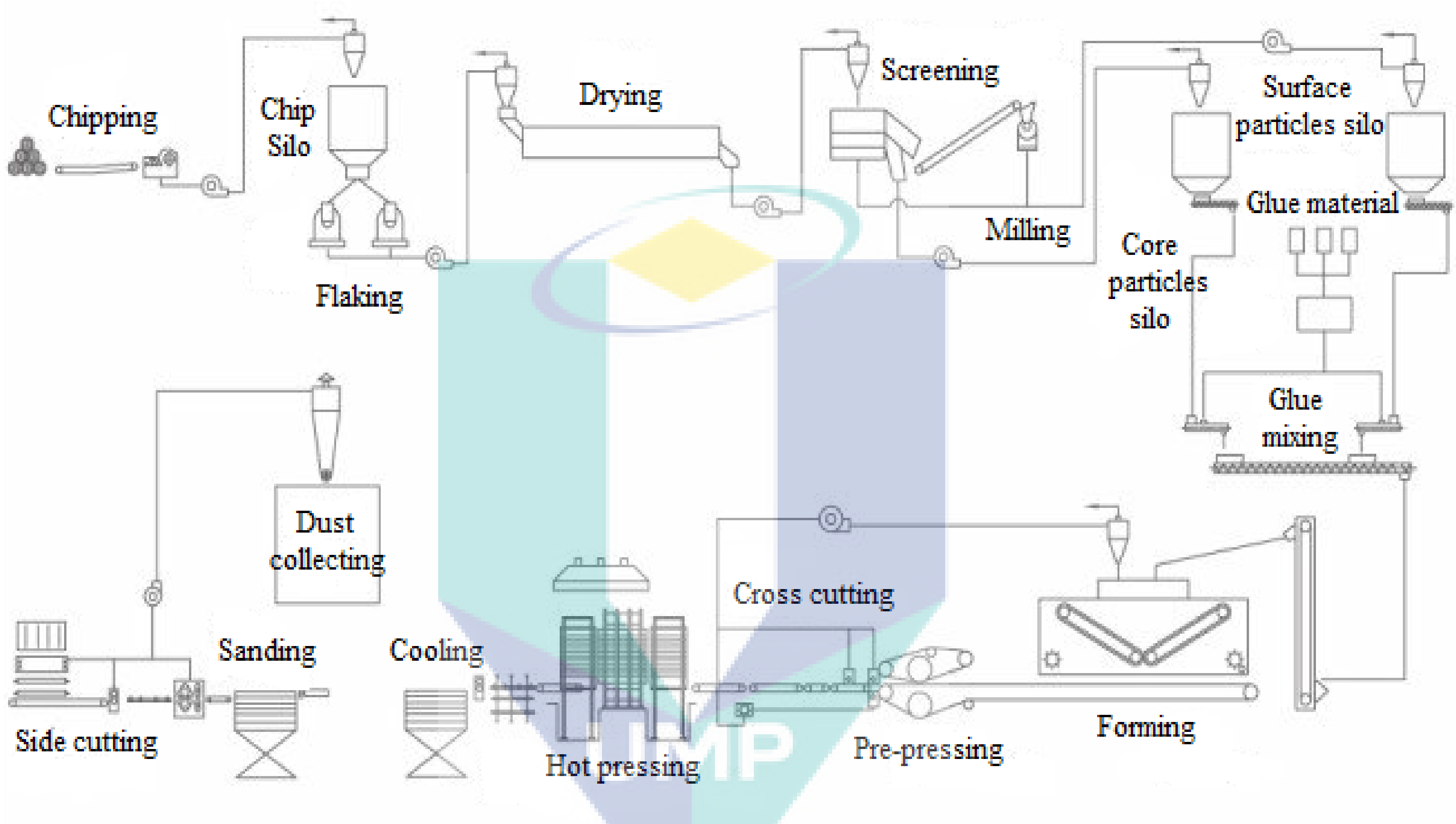

Figure 3.3: Process flow diagram

3.1.1 Process Description

The general steps used to produce MDF include chipping raw material, refining, drying, blending fibers with resin or wax, forming the resinated material into a mat, and hot pressing. Figure 3.2 shows a schematic drawing of the dry forming MDF-process. Firstly, oil palm fronds are delivered by truck or rail from oil palm plantations. If the raw materials are prepared onsite, logs are debarked, cut to more manageable lengths, and then sent to chippers. If necessary, the fronds are washed to remove dirt and other debris, then, transported into a pressurized refiner chamber. In the refiner chamber, single or double revolving disks are used to mechanically pulp the fronds into fibers suitable for making the board.

From the refiners, the fibers move to the drying and blending area. A rotary predryer may be used for initial drying of relatively wet furnish. Regardless of whether or not a predryer is used, tube dryers typically are used to reduce the moisture content of the fibers to desired levels. Heat is usually provided to tube dryers by the direct firing of propane, natural gas, or distillate oil or by indirect heating.

The sequence of the drying and blending operations depends on the method by which resins and other additives are blended with the fibers. In this type of manufacturing, Urea-formaldehyde (UF) resins are used. Some plants inject resins into a short-retention blender, while most facilities inject resin formulations into a blowline system. If resin is added in a separate blender, the fibers are first dried and separated from the gas stream by a fiber recovery cyclone, then conveyed to the blender. The fibers then are blended with resin, wax, and any other additives and conveyed to a dry fiber storage bin.

If a blowline system is used, the fibers are first blended with resin, wax, and other additives in a blowline, which is a duct that discharges the resinated fibers to the dryer. After drying, the fibers are separated from the gas stream by a fiber recovery cyclone and then conveyed to a dry fiber storage bin.

Air conveys the resinated fibers from the dry storage bin to the forming machine, where they are deposited on a continuously moving screen system. The continuously formed mat must be prepressed before being loaded into the hot press. After prepressing, some pretrimming is done. The trimmed material is collected and recycled to the forming machine.

The prepressed and trimmed mats then are transferred to the hot press. The press applies heat and pressure to activate the resin and bond the fibers into a solid panel. The mat may be pressed in a continuous hot press, or the precompressed mat may be cut by a flying cutoff saw into individual mats that are then loaded into a multi-opening, batch-type hot press. Steam or hot oil heating of the press platens is common in domestic MDF plants. After pressing, the boards are cooled, sanded, trimmed, and sawed to final dimensions. The boards may also be painted or laminated. Finally, the finished product is packaged for shipment.

3.2 RAW MATERIALS AND EQUIPMENTS NEEDED

3.2.1 Raw Materials

The raw materials for this production of MDF can be 100% of oil palm fronds (OPF) or in mixture with other fibres of raw materials. The most common types of conventional synthetic adhesives applied in this production of MDF are urea-formaldehyde (UF), melamine-urea-formaldehyde (MUF), and phenol-formaldehyde (PF) resins while the most common non-formaldehyde wood-based adhesive is the methylene diisocyante diphenyl (MDI) resin which is more expensive than the previous ones.

3.2.2 Equipment

MDF from oil palm fronds production line is not much differs with the conventional MDF production line which include as well as single machine equipment such as chipper, refiner, dryer, forming machine, pre-press, hot press and other machines. The complete constructions of MDF production line equipment are listed as follows:

1) Wet Storage System Equipment
2) Fiber Preparation Line Equipment
3) Gluing System Equipment
4) Dryer Unit Equipment
5) Forming Unit Equipment (Before Press)
6) Hot Press Line Equipment
7) Sanding & after Press Line Equipment
8) Dust extraction System Equipment
9) Utility Unit Equipment
10) Structures and supports

3.3 EVALUATION OF MEDIUM-DENSITY FIBREBOARD (MDF) FROM OIL PALM FRONDS (OPF) PROPERTIES

3.3.1 Oil Palm Fronds Properties

Resinated and dried oil palm fronds fibres were sampled after the dryer cyclone. The size and shape of fibres were measured by image analysis using a laser-based PQM 1000 pulp quality monitoring system.

3.3.2 Mechanical Properties of MDF from Oil Palm Fronds

Oil palm fronds MDF panels were cut into 50 × 50 mm^2 pieces for determining of Internal Bonding (IB) and measuring density profiles. Bending strength, modulus of rupture (MOR) and modulus of elasticity (MOE) were measured on 4 × 32 cm^2. The mechanical properties IB, MOR, and MOE, were determined according to the EN standard methods (EN 310, 1993; EN 319, 1993) in an Alvetron TC 10 testing instrument. The pressed panels were stored for one week at room temperature after pressing. Before testing, the specimens were conditioned in a room for 48 h at 65% relative humidity and a temperature of 20 °C. Oil palm fronds MDF were tested according to (American Society for Testing Materials, 2006).

3.3.3 Resin content of Oil Palm Fronds MDF

The urea-formaldehyde (UF) resin content was analyzed using the Kjeldhal method and the nitrogen content of the finished oil palm fronds MDF panels was measured using the Kjeltec System 1026 Distilling Unit.

3.3.4 Thickness Swelling of Oil Palm Fronds MDF

Thickness swelling (TS) properties were determined according to the EN standard (EN 317, 1993) of 50 × 50 mm^2 pieces of oil palm fronds MDF. The specimens were immersed vertically in water for 24 h to determine thickness and weight. Oil palm fronds MDF were tested according to (American Society for Testing Materials, 2006).

3.4 RISK ASSESSMENT AND MANAGEMENT

3.4.1 Emissions

The atmosphere created by machining MDF usually contains wood dust, volatile organic compounds (VOCs), and condensable particulate matter (PM). The primary emission sources at MDF mills are fiber dryers and press vents. Other emission sources may include boilers, chip production operations, and finishing operations such as sanding, trimming, and laminate application. Wood storage piles are sources of fugitive PM and VOC emissions.

Emissions from board hot presses are dependent on the type and amount of resin used to bind the wood fibers together, as well as wood species, wood moisture content, wax and catalyst application rates, and press conditions. When the press opens, vapors that may include resin ingredients, such as formaldehyde and other VOCs are released. The rate at which formaldehyde is emitted during pressing and board cooling operations is a function of the amount of excess formaldehyde in the resin, board thickness, press temperature, press cycle time, and catalyst application rates.

Emissions from finishing operations for MDF are dependent on the type of products being finished. For most MDF products, finishing involves trimming to size, sanding, and in some cases application of laminates. Other products may require sanding or the application of laminate surfaces with spray adhesives. Trimming and sanding operations are sources of PM, PM-10 emissions and PM-2.5 emissions.

3.4.2 Control of Emissions

Methods of controlling particulate matter (PM) emissions from MDF sources include absorption systems (wet scrubbers), fabric filters, wet electrostatic precipitators (WESPs), and oxidation systems. The WESP uses electrostatic forces to attract pollutants to either a charged metal plate or a charged metal tube. The collecting surfaces are continually rinsed with water to wash away the pollutants. Wet PM control systems may achieve short-term reductions in emissions of some water-soluble organic compounds such as formaldehyde.

A VOC control technology commonly used in the wood products industry for controlling both dryer and press exhaust gases is regenerative thermal oxidation. Thermal oxidizers destroy VOCs and condensable organics by burning them at high temperatures. Thermal oxidizers also reduce carbon monoxide (CO) emissions in direct-fired dryer exhausts by oxidizing the CO in the exhaust to carbon dioxide, CO_2 (a product of complete combustion).

In addition to add-on thermal or catalytic oxidizers, exhaust gases from dryers and presses may be routed to the combustion chamber of an onsite boiler or process heater. The VOC and CO emissions in the process exhaust may be incinerated in the combustion chamber provided that the system is designed to allow for sufficient mixing and residence time.

Fugitive PM emissions from road dust and uncovered bark and dust storage piles may be controlled in a number of different ways. Some of these methods include enclosure, wet suppression systems, and chemical stabilization.

In addition to the most appropriate risk management strategy for MDF is the one currently recommended by Health, Safety and Executive (HSE) that specifies:

1) The level of dust arising from the machining of MDF should be kept as low as reasonably practicable below the maximum exposure limits (MELs) for softwood dust and hardwood dust; and
2) Levels of free formaldehyde should be kept as low as reasonably practicable below the MELs for formaldehyde.

3.5 SITE SELECTION & PLANT LAYOUT

3.5.1 Site Selection

The geographical location of the final plant can have strong influence on the success of an MDF industrial venture. Considerable care must be exercised in selecting the plant site, and many different factors must be considered. Primarily, the MDF plant should be located where the minimum cost of production and distribution can be obtained, but other factors, such as space for expansion and safe living conditions for plant operation as well as the surrounding community, are also important.

The choice of the final MDF site should first be based on a complete survey of the advantages and disadvantages of various geographical areas and, ultimately, on the advantages and disadvantages of available real estate. There are several factors that should be considered in selecting a MDF plant site such as raw materials availability, site characteristics, transportation, utilities supply, as well as labour/manpower supply.

The site selection for oil palm fronds MDF plant should conveniently located near to the raw-material supplier (Oil-palm plantation) in order to reduce the transportation and distribution costs. Since Malaysia is one of the largest producers of oil palm biomass, there will be a constant supply of oil palm fronds throughout the country. Table 3.1 shows area covered under oil palm plantation in Malaysia.

It is preferable to build the MDF plant in peninsular of Malaysia due to the high demand of MDF compared to in Sabah and Sarawak. Pahang has the second largest area of oil palm plantation after Johor and has only one MDF manufacturer located there. So, Pahang has been identified as a potential place for oil palm fronds MDF plant compared to other state that already have several number of MDF manufacturers. The specific location suggested for oil palm fronds MDF plant is at Gebeng Industrial Estate, Pahang due to several factors as follows:

Table 3.1: Area under oil palm in Malaysia

State	Area (million hectares)
Sarawak	1.021
Sabah	1.432
Kelantan	0.129
Terengganu	0.167
Pahang	0.695
Malacca	0.053
Johor	0.721
N. Sembilan	0.165
Selangor	0.134
Perak	0.387
Kedah	0.081
Penang	0.014

Source: The Star (2012)

3.5.1.1 Road networks

Gebeng is located only 25 km from Kuantan and 5 km from Kuantan Port. The new Gebeng by-pass will see the ease of traffic flow between Gebeng Industrial Estate and Kuantan Port. The by-pass will directly link with the East West Expressway to connect Kuala Lumpur with Kuantan. This will provide a cost-effective means of transportation and greater accessibility in the transfer of MDF products from Gebeng Industrial Estate to the domestic and international markets. This will also greatly increase the viability of Kuantan Port in the domestic and international freights movements on a land bridge concept. This 169 km highway also provided cost effectiveness of transportation and greater accessibility in the transfer of oil palm fronds MDF to the rest of Malaysia.

3.5.1.2 Airport

The Sultan Ahmad Shah Airport is situated just 12 km from Kuantan. Malaysia Airlines, the national carrier and the other airlines, operate flights daily between Kuantan and Kuala Lumpur. There is a number of companies that provide comprehensive containerized cargo transportation services such as container haulage, freight forwarding, warehousing, distribution related services, port customs clearance and container repair, leasing and maintenance.

3.5.1.3 Water Supply

Water supply is sufficient and is fully treated, meeting with International World Health Organization standards for drinking water. The Jabatan Bekalan Air Negeri Pahang is responsible for ensuring an effective water supply system as shown in table below:

Table 3.2: Water supply in industrial estates

Name of estate / other areas supplied by some water treatment plant	Source of water supply (treatment plant)	Capacity of source (liters / day)
Bentung, Bentung II A, Bentung II B	Bentung plant phase II	45
Gebeng, Gebeng II	Semambu plant	144
Semambu, Jaya Gading,	Semambu plant	144

Indera Mahkota		
Peramu, Peramu II	Peramu plant	4.55, upgraded by 1995
Maran, Maran II	Simpang Jengka plant	8.18
Jerantut	Bukit Embun plant	18
Songsang	Lembuk Kawah plant	16, upgraded by 1995
Rompin	Rompin plant	5

Source: Danial, A. et al., 2008

3.5.1.4 Electric Power Supply

Tenaga Nasional Berhad (TNB) provides the generation of electricity. TNB's current capacity stands at 132kV tapped from 275kV line. The voltage maximum available is 220-240V. Tenaga Nasional Berhad can supply sufficient electricity that will provide about 800MW by year 2006.

Table 3.3: Electricity supplies in industrial estate

Location of industrial estate	Capacity of substation
Gebeng	Tanjung Gelang, 2 x 15 MVA
Kuantan port	Tanjung Gelang, 2 x 15 MVA
Semambu	Semambu, 2 x 15 MVA

Source: Danial, A. et al., 2008

3.5.1.5 Port (Kuantan Port)

Kuantan port, run by the Kuantan Port Consortium Sdn. Bhd is the major entry and exit point for sea borneo cargo in the East of Peninsular Malaysia. It is a deep-water, all-weather port that handles over 4 million tonnes of shipping a year. It is fully equipped to handle a wide variety of cargo, and has well-equipped conventional, multi-purpose container and liquid bulk wharves. Kuantan Port prides itself in providing a variety of excellent berthing facilities totalling 3,213 meters in length to cater to the various cargo compositions handled by the port.

These facilities include:

1. Multipurpose berths
2. Liquid chemical berths
3. Palm oil berths
4. Mineral oil berths
5. Container terminals

Initially designed to handle general cargo, Kuantan Port today has expanded itself into managing newer shipping trends and cargo packaging from break bulk to palletisation, unitization, dry bulk, containerization and liquid handling. It has dedicated facilities for liquid chemical products and container handling operations where two container berths measuring at 400 meters are available. Currently, 14 regularly container shipping services are available at Kuantan Port provided by 7 liner operators. Table below shows berthing facilities in Kuantan port.

Table 3.4: Berthing facilities in Kuantan Port

Berth	**Length (m)**	**Draught (m)**	**Displacement (tonnes)**
Container	200	11.2	45000
Multipurpose	525	11.2	45000
Palm oil berth (outer)	250	11.5	54000
Palm oil berth (inner)	150	8.0	8000

Source: Danial, A. et al., 2008

3.5.1.6 Human Resources

There are University Malaysia Pahang, 7 vocational schools, 1 technical schools, 1 MARA Institute of Technology, 1 polytechnics, 3 skill training institute in Pahang which provide courses designed to meet the manpower requirement of investors. In addition, the state government in collaboration with the private sector runs the Pahang Professional Development Institute (IKIP) and the Pahang Skill Development Centre (PSDC), both aimed at providing more skilled and semiskilled labour resources.

3.5.2 Plant Layout

The process units & ancillary buildings of MDF plant should be laid out to give the most economical flow of materials & personnel around the site. Hazardous processes must be located at a safe distance from other buildings. Consideration must also be given to the future expansion of the site. The ancillary buildings & services required on a site, in addition to the main processing units will include.

1. Storages for raw materials & products: tank farms & warehouses.
2. Maintenance workshops.
3. Stores for maintenance & operating supplies.
4. Laboratories for process control
5. Fire stations & other emergency services.
6. Utilities: steam boilers, compressed air, power generation, refrigeration, transformer stations.
7. Effluent disposal plant.
8. Offices for general administration.
9. Canteens & other amenity buildings, such as medical centres.
10. Car parks

When roughing out the preliminary site layout, the process units will normally be sited first & arranged to give a smooth flow of materials through the various processing steps, from raw material to final MDF product storage. Process units are normally spaced at least 30m apart; greater spacing may be needed for hazardous processes. In order to comply with Worker's Compensation Board and other environmental regulations applicable to the manufacturing sector, the installation of dust collection devices and an air circulation system are important to reduce the levels of volatile organic compound (VOC) emissions from the solvents and paints used in the manufacturing process.

The location of the principal ancillary buildings should then be decided. They should be arranged so as to minimize the time spent by personnel in travelling between buildings. Administration offices & laboratories, in which a relatively large number of people will be working, should be located well away from potentially hazardous processes.

Control rooms will normally be located be adjacent to the processing units, but with potentially hazardous processes may have to be sited at a safer distance. The sitting of the main process units will determine the layout of the plant roads, pipe alleys & drains. Access roads will be needed to each building for construction & for operation & maintenance.

Utility buildings should be sited to give the most economical run of pipes to & from the process units. Cooling towers should be sited so that under the prevailing winds the plume of condensate spray drifts away from the plant area & adjacent properties. The main storage area should be placed between the loading & unloading facilities & the process units they serve. Storage tanks containing hazardous materials should be sited at least 70 m from the site boundary. Figure 3.4 shows the preferred plant layout for oil palm fronds MDF plant.

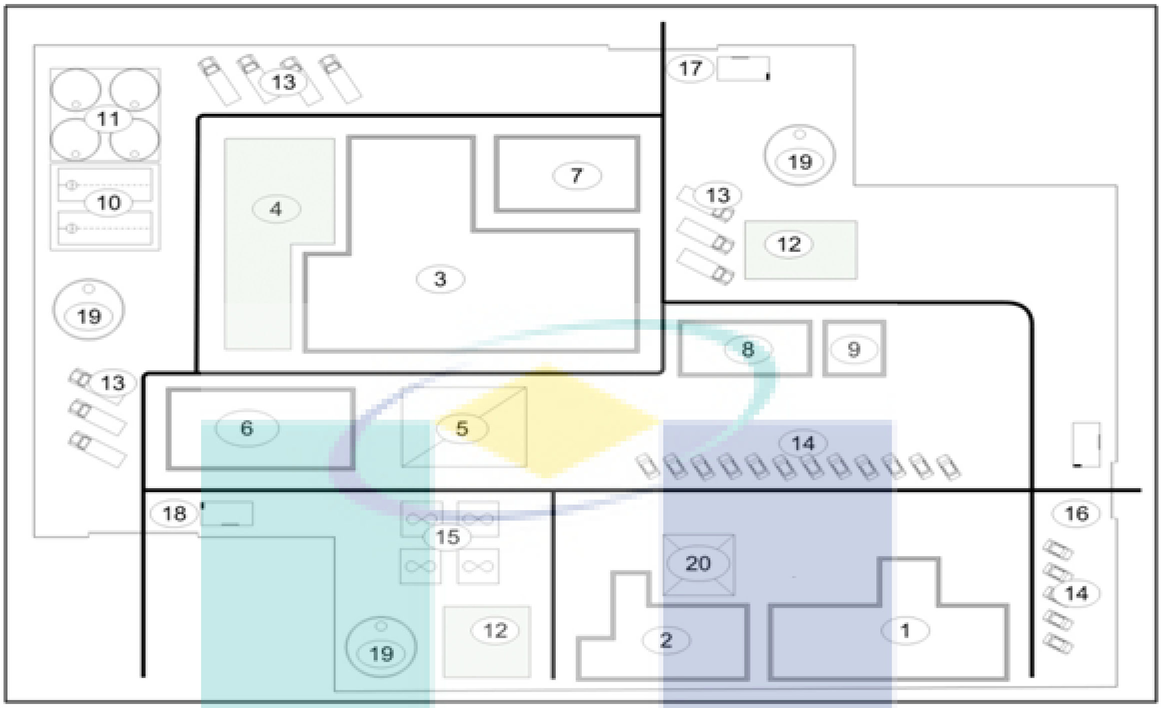

Figure 3.4: Plant Layout

Legend:

1.	Office	11.	Solid waste
2.	Laboratory	12.	Emergency assembly area
3.	Plant area	13.	Trailer park
4.	Expansion site	14.	Car park
5.	Main control	15.	Cooling tower
6.	Raw material storage	16.	Main entrance
7.	Product storage	17.	Production entrance
8.	Workshop	18.	Raw material / waste management entrance
9.	Workshop Store	19.	Backup water storage
10.	Liquid waste	20.	Surau

CHAPTER 4

RESULT AND DISCUSSION

4.1 QUALITY OF MEDIUM-DENSITY FIBREBOARD (MDF) FROM OIL PALM FRONDS (OPF)

4.1.1 Physical and Mechanical Properties

The results revealed from previous research showed that MDF produced from 100% OPF and its mixture offer good mechanical and swelling properties (Table 4.1). Several process optimizations were done and finalized, mainly at the refining stages of OPF fibre to make it suitable for MDF production and to meet the minimum standard requirements.

Table 4.1: Properties of MDF from Oil Palm Fronds with Different Blending Ratios

OPF blending ratio	MOE (N mm^{-2})	MOR (N mm^{-2})	IB (N mm^{-2})	TS (%)
100%	2 870.33	32.42	1.12	14.26
5%	2 693.84	32.87	1.17	13.62
10%	3 514.95	43.89	1.05	13.54
15%	3 861.49	44.36	1.26	13.76
20%	3 953.23	45.43	1.28	13.44
EN STD (622-5,2006)	>2 500	>22	>0.6	<15

Note: MOE - Modulus of elasticity
MOR – Modulus of Rupture
IB – Internal bond
TS – Thickness swelling

Source: N. Ashila and G.F. Najumudden. 2011

Based on the results shown, fibreboards produced from 100% OPF exhibited excellent results in which MOR, MOE and IB are positively related with each other to all the physical properties. Although it gives highest value for thickness swelling, the value is still acceptable with the commercialize standard. For instance, this type of problem can be overcome through the addition of other materials that have low water and solvent absorption. The average value of the properties also fulfilled the requirements as stipulated in European Standard (EN 622-5, 2006). From these results, it indicates that OPF is a suitable raw material for the production of MDF.

The properties of partially substituting rubberwood and mixed tropical hardwood in panel production also was conducted with blending ratios of OPF from 5%-20%. The analysis revealed that the mechanical properties increased with increased OPF blending ratio. The blending test and internal bonding results showed higher values for OPF mixture boards meet the standard requirements. Inclusion of higher amount of hydrophobic substance is required for MDF from OPF for better dimensional stability.

Table 4.2 shows physical and mechanical properties from another research done by (Ashila, 2011). In this research, two physical properties are being considered which are density and percentage of thickness swelling (%TS). The density of the treated OPF fibre particle board is found out less than the density of untreated OPF fibre particle board (Figure 4.1). However, these values are comparable with the industrial grade value which is still in the range of 664.77-720.83kg/m^3.

From the TS analysis, the result yield shows that the untreated OPF fibre are better than the treated OPF fibre which it absorb less amount of water and swelled less than the treated sample. In contrast with samples contain waste tires composition, as the waste tires composition increases, the amount of thickness swelled is decreases. This might cause by the tires characteristic which it low value of water and solvent absorption.

Table 4.2: Physical properties of palm fronds fibre-waste tires particle board

No.	OPF fibre condition	Composition, %		Physical properties, (average)		
		OPF fibre	Waste tires	Density, kg/m^3	%TS, 1hr	%TS, 12 hrs.
1	Untreated	100	0	673.75	28.471	40.036
2	Treated	100	0	653.08	90.407	110.64
3	Treated	80	20	657.49	45.161	52.957
4	Treated	60	40	689.56	34.573	40.155
5	Industrial standard	ANSI M-2*(1)		672.78-720.83	-	-
6		ANSI M-S*(1)		640.74-688.80	-	-
7		SierraPine Particleboard*(2)		720.83	-	-

*(1) from Duraflake® Particleboard Specification
(2) SierraPine Particleboard testing based on ASTM D1037

Source: N. Ashila and G.F. Najumudden. 2011

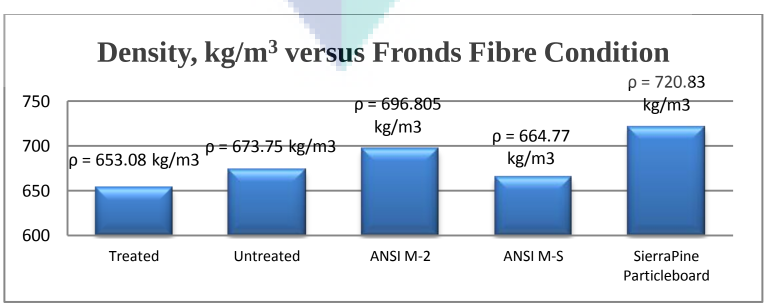

Figure 4.1: Density versus OPF fibre condition

In the research also, in term of mechanical properties, three properties are being considered which are Modulus of Rupture (MOR), Modulus of Elasticity (MOE) and Internal Bonding (IB) Strength. The data collected are compared with the commercial or industrial standard consists of ANSI M-2, ANSI M-S and SierraPine Particleboard standard testing based on ASTM D1037. All the properties measured in unit N/mm^2 were tabulated in Table 4.3:

Table 4.3: Mechanical properties of the OPF fibre-waste tires particle board

No.	**OPF fibre condition**	**Composition, %**		**Mechanical properties (average)**		
		OPF fibre	**Waste tires**	**MOR, N/mm^2**	**MOE, N/mm^2**	**IB strength, N/mm^2**
1	Untreated	100	0	14.2998	1607.489	0.3816
2	Treated	100	0	3.0141	340.624	0.0635
3	Treated	80	20	2.072	249.8449	0.026
4	Treated	60	40	1.2116	149.3019	0.0166
5	Industrial standard	ANSI M-2*(1)		12.997	2000.24	0.3999
6		ANSI M-S*(1)		10.998	1700.307	0.359
7		SierraPine Particleboard*(2)		13.1005	1999.55	0.448

*(1) from Duraflake® Particleboard Specification
(2) SierraPine Particleboard testing based on ASTM D1037

Based on the results, for 100% untreated OPF, it gives the highest value of MOR, MOE and IB strength which are 14.2998 N/mm^2, 1607.489 N/mm^2 and 0.3816 N/mm^2 respectively compare to other mixtures. These values give the steadiest reading for which still within the range and comparable with the industrial standard. As a conclusion, it indicates that OPF fibre has the best physical and mechanical properties which are suitable for replacement of rubberwood sources for MDF manufacturing

4.1.2 Sound Absorption Characteristics

Sihabut, T. and Laemsak, N. 2012 have investigated the sound absorption capacity of fibreboards produced from oil palm fronds treated by nine different combinations of cooking and refining processes. According to the research, it can be concluded that, like other porous materials, the higher the sound frequency, the better the sound absorption coefficients. Table 4.4 shows the result obtained for sound absorption coefficients.

Table 4.4: Sound absorption coefficients of oil palm frond fibreboards produced under various conditions. Data are presented as mean (standard deviation)

Condition No.	Sound Frequency (Hz) 250	500	1,000	2,000	Mean*
I	0.1200(0.0071)	0.2825(0.01106)	0.5925(0.0035)	0.5825(0.0177)	0.3944
II	0.1350(0.0071)	0.3125(0.0247)	0.5650(0.0636)	0.5350(0.0636)	0.3869
III	0.1300(0.0000)	0.2675(0.0247)	0.5375(0.0318)	0.7150(0.0424)	0.4125
IV	0.1300(0.0071)	0.2725(0.0247)	0.5825(0.0350)	0.6725(0.0106)	0.4144
V	0.1200(0.0000)	0.2050(0.0212)	0.4175(0.0350)	0.7500(0.0000)	0.3731
VI	0.1200(0.0000)	0.2775(0.0247)	0.5600(0.0424)	0.6350(0.0495)	0.3981
VII	0.1400(0.0071)	0.2825(0.0035)	0.4500(0.0495)	0.8475(0.0035)	0.4300
VIII	0.1275(0.0106)	0.2850(0.0141)	0.4200(0.0070)	0.8300(0.0424)	0.4156
IX	0.1250(0.0000)	0.2625(0.0460)	0.5675(0.0247)	0.7475(0.0601)	0.4256
CP1	0.1050(0.0071)	0.3200(0.0283)	0.4175(0.0389)	0.4850(0.0636)	0.3319
CP2	0.1050(0.0071)	0.2425(0.0035)	0.4775(0.0106)	0.6500(0.0424)	0.3688

* = Mean value is the average of the sound absorption coefficients at the frequencies of 250, 500, 1,000 and 2,000 Hz
CP1 = Comparable values for commercial samples of fibreboard with a density of 0.39 $g.cm^{-3}$ CP2 = Comparable values for commercial samples of fibreboard with a density of 0.32 $g.cm^{-3}$

Source: Sihabut, T. and Laemsak, N., 2012

Oil palm fronds fibreboard sample under condition number 7 produced the best sound absorption capacity probably due to the fibre characteristics of this sample as a result of being subjected to the most severe treatment, so that the softness and numerous fibrillated fibres formed an optimum porosity board which was not too tight or loose. Once the sound energy hit these sample boards, friction, air viscosity and vibration due to sound movement inside the tortuous parts of these materials were greater than for the other board samples. Therefore, the energy that was converted to other types of energy, such as heat, was relatively greater, resulting in the greatest sound absorption. Figure 4.2 shows the absorption characteristics at different frequencies.

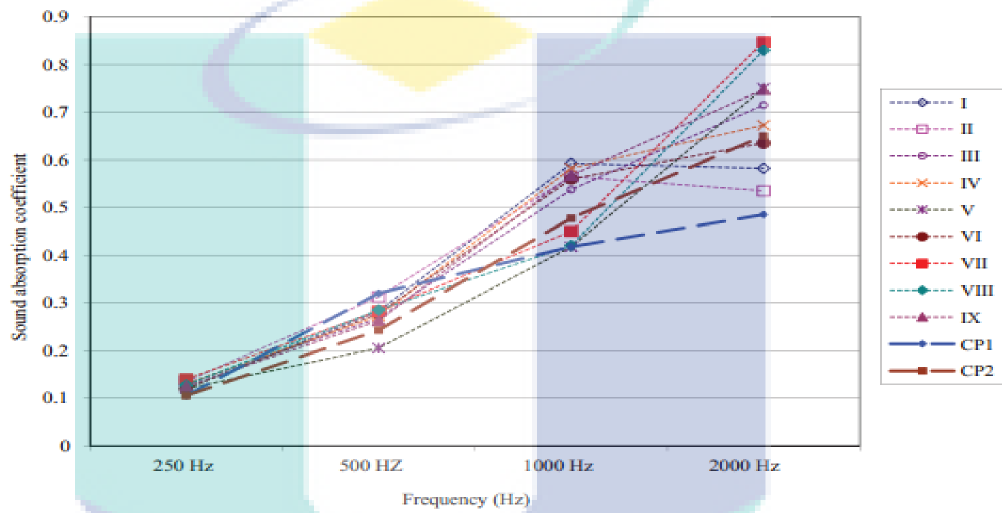

Figure 4.2: Sound absorption characteristics of oil palm fronds fibreboard samples (I to IX) produced under various conditions and of compared materials (CP1 = Commercial samples of fibreboard with a density of 0.39 $g.cm^{-3}$; CP2 = Commercial samples of fibreboard with a density of 0.32 $g.cm^{-3}$)

Source: Sihabut, T. and Laemsak, N. 2012

As a conclusion, in comparison to commercialize fibreboard samples with densities of 0.33-0.32 $g.cm^{-3}$ with the same thickness and intended uses, the oil palm fronds fibreboard sample had sound absorption qualities that were generally superior at several frequencies.

4.2 ECONOMIC ANALYSIS

The processing costs for manufacturing of MDF from OPF with those of conventional MDF are almost share similar values. The only difference for economic evaluation of this technology is focused on the pre-treatment and mobilization of the raw material itself in which the cost includes collection, chipping and transportation. Table 4.5 shows the comparison of average estimated material cost for oil palm fronds and rubberwood. Within a 100 km radius from MDF plant, the estimated cost of OPF chips delivered is RM 60 t^{-1} whereas for delivered rubberwood, the current price is at RM 130 t^{-1}. From the table, it shows that OPF has a lower material cost compared to rubberwood, that is cheaper by RM 39 t^{-1}. For instance, at 20% OPF blending ratio, it was estimated that for an MDF plant with daily production capacity of 400 m^3, the material cost savings will be RM 3 900 per day. Recent review also indicated that the cost of transporting oil palm fronds appears reasonable with average estimated transportation cost is RM (70.00 – 100.00) t^{-1} lorry load of petiole (M. Husin et al., 2002) compare with the transportation cost of rubberwood which is more expensive.

Table 4.5: Average estimated material cost for oil palm fronds and rubberwood

	Oil Palm Fronds	**Rubberwood**
RM t^{-1} (green)	60	130
Dry weight (t)	0.333	0.625
Dry tone price (RM)	208	180
Loss (%) (Debarking + Fine chip)	5	17
Dry yield (t)	0.317	0.519
Price after loss (RM t^{-1})	189	250
Weight at 60% MC (t)	0.507	0.83
Price at 60% MC (RM t^{-1})	118	157
Price difference (RM t^{-1})	39	-

Source: M. Husin et al., 2002

The feasibility of this production of MDF is also evaluated based on economics point of view. The economic calculation is based on the MDF production of 100 000 m^3 per year. The estimated grass root capital, fixed and total capital investment cost, manufacturing and total production cost, break even analysis and cash flow analysis are showed in the appendix.

The cash flow analysis is important to determine the payback period (PBP), the discounted break-even period (DBEP), and net present value (NPV) of the MDF plant. Payback period is the time that must elapse after start-up until cumulative undiscounted cash flow repays fixed capital investment. In short, payback period is the point where undiscounted cash flow rise to the level of negative working capital. An undiscounted cash flow is calculated to get the pay back value. With reference to the appendix A7, it is found that the payback period is roughly equals to 4.4 years. The time taking for construction of the plant and installation of equipments might the possible factors that contribute to the long period.

From the calculation (Appendix A3), it is found that the total cost of production of MDF from OPF is RM 397.44 per m^3. This price of MDF can be considered as a reasonable price compare to the existing commercialize MDF from rubberwood in which the cost are in the range of RM 489.68 - 1071.18 per m^3. From this calculated value, the break even analysis is then determined. Break-even point (BEP) is the point at which cost or expenses and revenue are equal that is no net loss or gain. Once the break-even point is achieved, the following revenue gain can be considered as profit. Based on the calculation, to break even, 968 m^3 of MDF from oil palm fronds need to be sold monthly. Since the production capacity of MDF is 8 333 m^3 per month based on this calculation, by selling 968 m^3 of MDF is quite high enough to get a big profit for the plant. In addition, from the calculation, the profitability margin calculated is 97.56% So, in terms of the economic feasibility study, the results are best for MDF from OPF compared to MDF produced from rubberwood sources. Table 4.6 show the costing summary for oil palm fronds MDF.

Table 4.6: Costing Summary

Current rubberwood MDF price per m^3	RM 824.499
Oil palm fronds MDF price per m^3	RM 417.35
Profit per m^3	RM 407.149
Annual profit gain	RM 40,714,900
% profitability margin	97.56%

4.3 EVALUATION OF COMPETITIVENESS OF MDF FROM OPF IN MALAYSIA

Malaysia now has eight MDF mills, mostly using rubberwood as their major raw material. Table below shows some of the other Malaysian MDF manufacturers simultaneously.

Table 4.7: Major MDF Manufacturers in Malaysia

	Annual Capacity (m3)	Range Of Thickness (mm)	Wood specie	Location Of Plant
Merbok Hilir Group*	350,000	2.2 – 32.0	Rubberwood	Merbok, Kedah & Masai, Johor
Evergreen Group	280,000	2.5 – 18.0	Rubberwood	Parit Raja (Batu Pahat) & Pasir Gudang, Johor
Hume Fibreboard	200,000	8.0 – 24.0	Rubberwood	Nilai, Negri Sembilan
Robin Resources	175,000	3.0 – 25.0	Rubberwood	Mentakab, Pahang
Donghwa Fibreboard	130,000	n.a.	Rubberwood	Nilai, Negri Sembilan
Guthrie MDF	130,000	3.0 – 25.0	Rubberwood	Kulim, Kedah
Segamat Panel Boards	72,000	2.3 – 6.0	Rubberwood	Segamat, Johor
Samling Fibreboard	100,000	1.5 – 18.0	Natural forest wood	Miri, Sarawak

* Merbok MDF and Takeuchi MDF

Source: Respective companies

Compare to other MDF products in Malaysia, MDF from Oil Palm Fronds is offering strategically lower price than other competitors' product since it is using low cost raw material. Even though at lower prices, the quality provided are very good and comparable with the existing standard commercialized MDF. In fact, it shows some improvement in certain specification such as strength and internal bonding. These are proven by physical and mechanical testing that have been discussed earlier. Since other MDF manufacturers produce the same items, MDF products compete primarily on price, the better price is usually preferable. Quality is another area of competition. So, in terms of competitiveness, the competition is not very intense for MDF from OPF because of its good quality and affordable prices.

CHAPTER 5

CONCLUSION

In this research, within the range of scope studied, it was observed that the MDF board from Oil palm fronds (OPF) showed very good internal bonding and acceptable tensile strength in characteristics. These important characteristics enable the incorporation of oil palm fronds in the existing industrial plant for MDF production purposes. The board surface was coarse, darker and contained a high number of black spots. However, the coarseness and undesirable surface of the MDF can be resolved by finishing it with stain and clear lacquer or by pigmented paint on top of the board surface.

In anticipation of the fact that the supply of rubberwood will be significantly reduced with the decreasing hectare under rubber plantation, existing MDF manufacturers should consider using at least a portion of their material from oil palm fronds due to the factors as follows:

1) Pioneer for eco-friendly palm fibreboard in Malaysia.
2) Use green technology by shredding fibre from raw materials (OPF), that is has no economic value into raw material
3) The production of this products show concern on Global Warming/ Climate Change Issues since it helps to reduce source from wood supply
4) Provide high quality value-added Medium-density Fibreboard (MDF) which is comparable to wood-based fibreboards at lower cost.

In terms of economic analysis, MDF from Oil Palm Fronds (OPF) will provide competitive advantages which give a lower price, combined with the good quality provided. It also offers a great opportunity for MDF manufacturers to overcome the problem of drastic fall in forest resource especially rubber wood resource. Effective utilization of fast-growing non-wood lignocelluloses materials and agro-wastes such as oil palm fronds has been of great alternative to overcome this problem.

MDF products produced from oil-palm fronds (OPF) which is environmentally friendly compare to other commercialized MDF products will be successful in the valley area by targeting those customers who wish MDF at an affordable price. It also can gain a niche in the market area and will be able to generate highly predictable cash flows on a monthly basis from the manufacturing and distribution of these products. So, in term of market viability, this product will generates sustainable profits over a period of time and will continues to make profit in long-term survival. In conclusion, the production of oil palm fronds MDF has a very economic feasible of manufacturing in Malaysia.

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APPENDIX

APPENDIX A

The economic calculation is based on the production of 100 000 m^3 of oil palm fronds MDF per year. The estimated cost for MDF production line for 100 000 m^3/year is $ 1,694,824 per unit. (www.alibaba.com). This value was used as reference for the total bare module cost (TBM) in this calculation.

A1: Grass Root Capital

Total Bare module cost (TBM)	RM 5,175,486.92
Contingency and fees (8%) x TBM	RM 414,038.95
Auxiliary facilities (10%) x TBM	RM 517,548.69
Grass Root capital (GRC)	**RM 6,107,074.57**

A2: Fixed and Total Capital Investment cost

Direct Cost

Item	**Factor**	**Cost**
Onside		
Equipment installation	0.3 GRC	RM 1,832,122.37
Piping installation	0.4 GRC	RM 2,442,829.83
Instrumentation and control	0.15 GRC	RM 916,061.18
Electrical and material	0.08 GRC	RM 488,565.97
Offside		
Building	0.1 GRC	RM 610,707.46
Yard improvement	0.01 GRC	RM 61,070.75
Land	0.02 GRC	RM 122,141.49
Service Facilities	0.05 GRC	RM 305,353.73
Total		**RM 6,778,852.77**

Indirect Cost

Item	Factor	Cost
Contingency	0.1 GRC	RM 610,707.46
Construction Expense	0.08 GRC	RM 488,565.97
Engineering and supervision	0.05 GRC	RM 305,353.73
Contractor's Fee	0.15 GRC	RM 916,061.18
Total		**RM 2,320,688.33**

Total cost = *Direct cost + Indirect Cost*
= **RM 9,099,541.10**

Fixed Capital Investment (FCI) = *Total cost + Grass roof Capital*
= **RM 15,206,615.67**

Working Capital = *12% of FCI*
= **RM 1,824,793.88**

Start Up Cost = *8% of FCI*
= **RM 1,216,529.25**

Total Capital Investment = *Fixed Capital investment + Working Capital + Start Up cost*
= RM 18,247,938.80

A3: Manufacturing cost and Total Production Cost

Raw Material

Raw Material	Consumption (t/yr)	Price (RM/t)	Cost (RM)
Oil Palm Fronds	137,700	65	RM 8,950,500
Urea-Formaldehyde	7,706.23	2,100	RM 16,183,083
Total			**RM 25,133,583**

Total Variable Cost

No.	Item	Cost
1	Raw Material	RM 25,133,583
2	Makeup Water	RM 48,324.60
4	Power	RM 9,096,820
	Total variable cost	**RM 34,278,727.60**

Fixed Operating Cost

Items	Cost, RM/yr
Maintenance, take as 5% of fixed capital	RM 760,330.78
Operating labor	RM 2,537,964
Plant overheads, take as 50% of operating labor	RM 1,268,982.00
Laboratory, take as 20% of operating labor	RM 507,592.80
Capital charges, 10% of fixed capital	RM 1,520,661.57
Insurance, 1% of fixed capital	RM 152,066.16
Local taxes, 1% of fixed capital	RM 152,066.16
Royalties, 1% of fixed capital	RM 152,066.16
Fixed Operating Cost	**RM 4,513,765.62**

Cost of Sale

Item	**Cost**
Direct Research	RM 2,000,000.00
Sales expense, 1% of fixed cost	RM 152,066.16
General overheads, 1% of fixed cost	RM 152,066.16
Research and development, 1% of fixed cost	RM 152,066.16
Administrative expense	RM 486,649.45
Cost of sales	**RM 2,942,841.93**

Total Annual Operating Cost

Item	**Cost**
Variable Cost	RM 34,278,727.60
Fixed Cost	RM 4,513,765.62
Cost of sales	RM 2,942,841.93
Total Annual Operating Cost	**RM 41,735,335.15**
Total production cost of oil palm fronds MDF per m^3	**RM 417.35**

Plant cost (Total investment) =**RM 18,247,938.80**

Land cost = **RM 2,172,633.50**

Annual operating cost = **RM 41,735,335.15**

Income is estimated from the equation below:

Income, RM/year = Amount of MDF (m^3/year) x world price of MDF (RM/m^3)

Income, RM/year = 100 000 m^3/yr x RM 824.499/m^3

Income = **RM 82,449,900**

A4: Break Even Analysis

Break Even Point = Fixed Costs / (selling price - variable costs)

Monthly Break Even at 968 m^3

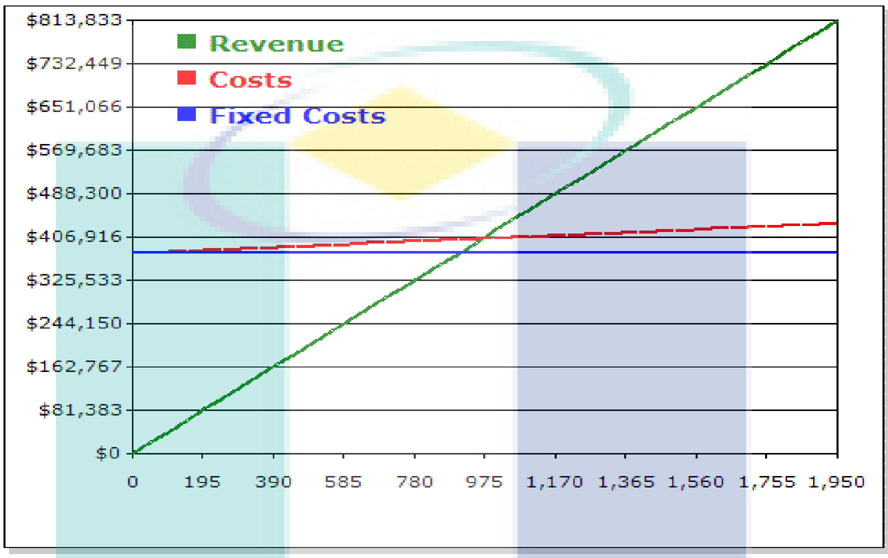

Figure 1: Graph of Break Even Point

A5: Cash flow analysis

Year	Investment(RM)	Income(RM)	Depreciation(RM)	Expense(RM)	Net profit (RM)	Tax(RM)	Profit After Tax (RM)	Net Cash Income (RM)	Sum Net Cash Income (RM)
0									
1	2,172,633.00				-2,172,633.00			-2,172,633.00	-2,172,633.00
2	3,041,323.13				-3,041,323.13			-3,041,323.13	-5,213,956.13
3	15,206,615.67				-15,206,615.67			-15,206,615.67	-20,420,571.80
4		57,714,930.00	1,090,094.80	41,735,335.15	14,889,500.05	4,020,165.01	10,869,335.04	10,869,335.04	-9,551,236.76
5		70,082,415.00	1,090,094.80	41,735,335.15	27,256,985.05	7,359,385.96	19,897,599.09	19,897,599.09	10,346,362.32
6		82,449,900.00	1,090,094.80	41,735,335.15	39,624,470.05	10,698,606.91	28,925,863.14	28,925,863.14	39,272,225.46
7		82,449,900.00	1,090,094.80	41,735,335.15	39,624,470.05	10,698,606.91	28,925,863.14	28,925,863.14	68,198,088.60
8		82,449,900.00	1,090,094.80	41,735,335.15	39,624,470.05	10,698,606.91	28,925,863.14	28,925,863.14	97,123,951.73
9		82,449,900.00	1,090,094.80	41,735,335.15	39,624,470.05	10,698,606.91	28,925,863.14	28,925,863.14	126,049,814.87
10		82,449,900.00	1,090,094.80	41,735,335.15	39,624,470.05	10,698,606.91	28,925,863.14	28,925,863.14	154,975,678.01
11		82,449,900.00	1,090,094.80	41,735,335.15	39,624,470.05	10,698,606.91	28,925,863.14	28,925,863.14	183,901,541.14
12		82,449,900.00	1,090,094.80	41,735,335.15	39,624,470.05	10,698,606.91	28,925,863.14	28,925,863.14	212,827,404.28
13		82,449,900.00	1,090,094.80	41,735,335.15	39,624,470.05	10,698,606.91	28,925,863.14	28,925,863.14	241,753,267.42
14		82,449,900.00	1,090,094.80	41,735,335.15	39,624,470.05	10,698,606.91	28,925,863.14	28,925,863.14	270,679,130.55
15	547,438.16	82,449,900.00	1,090,094.80	41,735,335.15	39,624,470.05	10,698,606.91	28,925,863.14	28,925,863.14	299,604,993.69

A7: Cash flow analysis graph

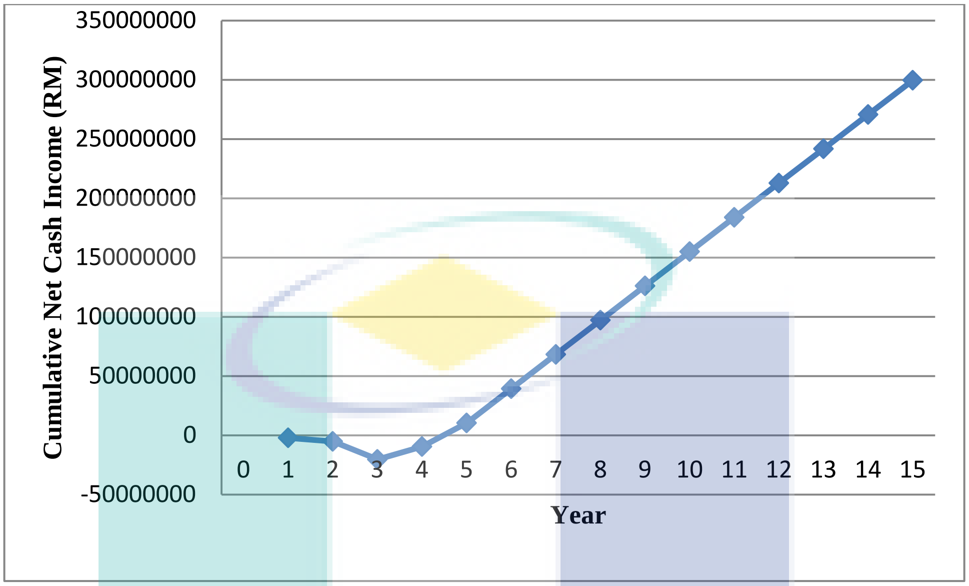

Figure 2: Payback period