# ANALYSIS OF SAP SUGAR AND STARCH CONTENT OF FELLED OIL PALM TRUNKS AT DIFFERENT STORAGE TIME

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# ANALYSIS OF SAP SUGAR AND STARCH CONTENT OF FELLED OIL PALM TRUNKS AT DIFFERENT STORAGE TIME

by

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AD | Air dry weight |
| ASTM | American Society for Testing and Materials |
| AVROS | Algemene Vereniging van Rubberplanters ter Oostkust van Sumatera |
| CBS | Cooperative Breeding Scheme |
| CTO | Column Oven |
| DDI | Distilled De-Ionized |
| DGU | On-Line Degasser |
| DP | Degree of polymerization |
| DOA | Department of Agriculture |
| FELDA | Federal Land Development Authority |
| FRIM | Forest Research Institute Malaysia |
| HPLC | High performance liquid chromatography |
| KLK | Kuala Lumpur Kepong Berhad |
| LC | Liquid Chromatography |
| OPGL | Oil Palm Genetic Laboratory |
| OPM | Oil palm of Malaya |
| OPT | Oil Palm Trunk |
| PORIM | Palm Oil Research Institute of Malaysia |
| MARDI | Malaysian Agricultural Research and Development Institute |
| MC | Moisture content |
| MPOB | Malaysia Palm Oil Board |
| MPOC | Malaysia Palm Oil Council |
| NaOH | Sodium Hydroxide |
| NIFOR | Malaysia and Institute for Oil Palm Research |
| OD | Oven dry weight |
| RID | Refractive Index |
| R&D | Research and Development |
| SBS | Sabah Breeding Schemes or programme |

| | |
|---|---|
| SEM | Scanning Electron Microscope |
| SI | System of Units |
| Socfin | Societe Financiere de Caoutchouces |
| UPB | United Plantations Berhad |
| UV-VIS | Ultraviolet/Visible Spectrometry |
| WIFOR | West African Institute for Oil Palm Research |
| Wv | Wavelength |

## LIST OF SYMBOL

| | |
|---|---|
| % | Percentage |
| °C | Degree Celsius |
| $g/cm^3$ | Grams per cubic centimeter |
| MPa | Megapascal |
| $\alpha$ | Alpha |
| m | Meter |
| mm | Millimeter |
| ml | Milliliter |
| rpm | Revolution per minute |
| g | Gram |
| psi | Pound force per square inch |

# ANALISIS KANDUNGAN GULA DAN KANJI BATANG KELAPA SAWIT YANG TELAH DITEBANG MENGIKUT MASA PENYIMPANAN YANG BERBEZA.

## Abstrak

Penyelidikan ini adalah untuk mengkaji potensi kebolehgunaan sap batang kelapa sawit sebagai bahan mentah untuk industry bio-ethanol. Sap daripada batang kelapa sawit telah di kaji. Kandungan gula dan kanji telah dianalisis berdasarkan kepelbagaian jenis baka, masa penyimpanan, usia pokok dan lokasi.

Empat jenis baka kelapa sawit telah digunakan untuk penyelidikan ini; Dura x Pisifera campur (Dura x URT), Dumpy x Yangambi x AVROS, Deli Dura x Yangambi (D3D x L236T) dan Deli Dura x Pisifera x H&C. Batang kelapa sawit yg telah ditebang kemudian disimpan pada masa penyimpanan yang berbeza; 0, 15, 30, 45 60 dan 75 hari, sebelum dipotong didalam bentuk disk. Disk itu kemudian telah dibahagi kepada 3 bahagian; dalam (A), tengah (B), dan luar (C). Setiap bahagian kelapa sawit itu kemudian telah di perah untuk mendapatkan sap segar. HPLC dan kaedah phenol sulphuric asid telah digunakan untuk menentukan kandungan jumlah keseluruhan gula dan individu gula. Penentuan kanji pula telah dijalankan dengan menggunakan kaedah Humprey dan Kelly. Struktur anatomi batang kelapa sawit telah di kaji dengan menggunakan SEM dan diambil dari bahagian pemotongan rentas. Penentuan sifat

fizikal telah dibuat iaitu penentuan kandungan lembapan dan ketumpatan berdasarkan standard ASTM.

Penentuan visual menunjukkan batang kelapa sawit mengandungi jumlah kandungan kanji yang banyak terutamanya di bahagian atas pokok kelapa sawit. Sementara sifat fizikal menunjukkan kandungan lembapan untuk semua baka adalah dari 147% hingga 1022% dan meningkat dari bahagian tengah ke luar. Dalam kajian ini, baka Deli Dura x Yangambi (D3D x L236T) telah dikenalpasti mengandungi kandungan lembapan yang tinggi berbanding sampel yang lain. Ketumpatan pula di kaji meningkat dari bahagian luar ke dalam. Baka Dumpy x Yangambi x AVROS telah dikenalpasti mempunyai ketumpatan yang tertinggi berbanding baka yang lain.

Penentuan kandungan gula pula menunjukkan kandungan gula yang dianggarkan melebihi 60% daripada keseluruhan pokok. Gula yang terdapat didalam sap dan meningkat apabila masa penyimpanan di panjangkan selepas penebangan terutamanya selepas hari ke 30 hingga 60 hari penyimpanan. Bahagian dalam dan tengah ( bahagian A dan B) telah di kenalpasti mengandungi kandungan jumlah gula keseluruhan yang tinggi dengan kehadiran tiga jenis gula utama glucose, sucrose dan fructose serta kandungan gula yang lain. Baka Cultivar Dura x Pisifera campur (dura x URT) menunjukkan kandungan gula keseluruhan di dalam sap yang tertinggi dengan kepekatan dari 43.82 mg/ml hingga 181.89 mg/ml dengan HPLC dan 38.94 mg/ml hingga 181.74 mg/ml dengan kaedah colometrik.

Keputusan kandungan kanji pula menunjukkan kandungan kanji tinggi di awal masa penyimpanan dan menurun disekitar hari ke 30 hingga 60. Jumlah purata kandungan kanji adalah 0.8% dan kandungan kanji tertinggi telah di jumpai di bahagian dalam (A) dan tengah (B). Baka Dumpy x Yangambi x AVROS telah di kenalpasti mempunyai kandungan kanji yang tertinggi dengan jumlah 0.07% dan 3.21% manakala baka Deli Dura x Yangambi (D3D x L236T) mempunyai kandungan kanji terendah diantara 0.06% dan 1.55% .

Kajian terhadap hubungkait kandungan lembapan dan kandungan gula menjumpai kandungan lembapan yang tinggi akan menyebabkan kandungan gula menurun. Kajian hubungkait kandungan gula dan kanji pula menunjukkan pengurangan kandungan kanji akan member kesan terhadap kandungan gula.

Batang kelapa sawit telah dikenalpasti sebagai bahan mentah yang sesuai digunakan untuk penghasilan bioethanol dengan menggunakan masa penyimpanan dan pemilihan jenis baka yang sesuai. Baka Dumpy x Yangambi x AVROS telah di kenalpasti sebagai baka yang berpotensi di gunakan untuk mencapai tujuan ini.

## ANALYSIS OF SAP SUGAR AND STARCH CONTENT OF FELLED OIL PALM TRUNKS AT DIFFERENT STORAGE TIME

### Abstract

This research investigated the potential use of oil palm sap as a feedstock for bioethanol production. Sap from squeezed oil palm trunks was investigated. The sugar and starch content were further analyzed based on various cultivars, storage time, age and location.

Four types of cultivars were used for the study that include; Dura x Pisifera mix (Dura x URT), Dumpy x Yangambi x AVROS, Deli Dura x Yangambi (D3D x L236T) and Deli Dura x Pisifera x H&C. The felled oil palm trunks were stored at a different duration of storage time; 0, 15, 30, 45, 60 and 75 days, before they were cut into discs. The disc was divided into 3 parts: inner (A), middle (B), and peripheral (C) parts, respectively. Each parts of the OPT was squeezed to obtain the fresh sap. High Performance Liquid Chromatography (HPLC) and phenol sulphuric acid method were used to determine the total sugar and individual sugar content of the sap. Starch in oil palm samples was analyzed using the method by Humphrey and Kelly. The anatomy structure of oil palm trunks was conducted through the Scanning Electronic Microscopy (SEM) and taken from the transverse section. The physical properties of the sample; moisture content and density, were investigated in accordance to American Society for Testing and Materials (ASTM) standard.

Microscopic investigation result showed that oil palm trunks contain abundant amount of starch especially in the upper part of oil palm tree. Based on the finding of this study on physical properties showed that moisture content for all cultivars are from 147% to 1022% and gradually increased from inner to peripheral zone. In this study, cultivar Deli Dura x Yangambi (D3D x L236T) was identified to contain highest moisture among others samples. The density is higher from peripheral part and progressively lower in the inner part. Cultivar Dumpy x Yangambi x AVROS has been found to be the highest density among to the other cultivars.

Sugar analysis showed the amount of sugar in the oil palm sap approximately more than 60% of the whole tree. Sugars exist in the sap and were found to increase as the storage time extended after felling especially after 30 to 60 storage days. The inner and middle parts (part A and B) were identified to contain highest total sugar content with presence of three main sugars glucose, sucrose and fructose and others sugars. Cultivar Dura x Pisifera mix (dura x URT) shows the highest total sugar in the sap with the concentration from 43.82 to 181.89 mg/ml obtained by HPLC and 38.94 to 181.74 mg/ml obtained by Colometric method.

The starch content started to be high at the initial storage time and decreases around day 30 to 60 of storage. The average amount of starch content was found about 0.8% and the highest starch content was found in the inner part (A) and middle part (B). Cultivar Dumpy x Yangambi x AVROS was recognized to contain highest starch level about 0.07% and 3.21% and Deli Dura x Yangambi (D3D x L236T) type contain lower starch content, around 0.06% and 1.55% .

Investigation on relationship of moisture content and sugar content found that higher moisture content will give lowest sugar content. Study on relationship of sugar content and starch content also showed that degradation of starch content is significant with the increase~~s~~ of the sugar content.

Oil palm trunks were indicated as a promising feedstock that is suitable for the production of bioethanol with the appropriate storage time and type of cultivar. In this study, cultivars Dumpy x Yangambi x AVROS was found to be the most potential cultivar to be used to achieve this target.

# CHAPTER 1
# INTRODUCTION

## 1.1 General Background

Oil palm, *Elaeis guineensis* is tropical tree species and grown well mostly in Africa, South East Asia and in America as a commercially crops for various usages mainly in the manufacturer of food products, soaps and detergents, cosmetics, resins, paints and etc. (Basiron and Weng, 2004; Lam *et al*., 2009). Oil palm was introduced into Malaysian in 1875 in the early 20$^{th}$ century. This valuable commercial plant were planted extensively and increased tremendously as a growing demand for source of edible oil. Currently, Malaysian has become one of the largest producers and exported approximately over 40% of the total world palm oil production with the total area of oil palm trees planted was more than 4 million hectares (Basiron and Weng, 2004; Chew and Bhatia, 2008). Increasing in demand of palm oil in the world market has stimulated the expansion of rapid replanting of the oil palm tree. Due to this scenario, massive amount of oil palm biomass has been produce as waste after the harvesting. Basically palm tree are felled an average age around 25 years as shown in Figure 1. Improper management of this biomass has become an environmental concern especially for Malaysia.

Figure 1: Felled oil palm biomass left at plantation after harvesting activities.

Several studies have been conducted to utilize this biomass into value added products. As a result, almost every portion of this tree also can be converted into usable material especially the oil palm trunks (OPT), which is can be used for the manufacturing plywood and production pulp and paper. Currently, new attention has been given to a production of bioethanol from agricultural crop such as corn, sugarcane, wheat and etc. However, competition between food industries due to source of human food makes production of bioethanol using this agricultural crop make it as international issue on food security. Oil palm biomass looks promising to replace this agricultural crop, due to its availability, lower cost and potential as a source of this bioenergy and has invited numerous researches to discover other usage of this biomass. The production of ethanol using oil palm biomass has been conducted before by using palm oil mill effluent and empty fruit bunches (Alam *et al.*, 2005). Other study have assessed to convert the empty fruit bunch (EFB) and palm press fiber into sugar by using cellulose enzyme to obtain sugar for further process (Gutierrez *et al*., 2009). Previous study discovers that acid hydrolysis method can be used to convert empty fruit bunch as a feedstock into sugar (Cheng *et al*., 2007). Lim *et al*., (1997) found that oil palm trunks show a promising result to be converted into glucose or sugar by using acid hydrolysis method. The purpose of this research is to provide information and develop a comprehensive method by using oil palm sap as main material to obtain the sugar and also tried to discover an effective cost for ethanol production.

Oil palm tree consist of 90% of biomass, mostly from the trunks part that could easily obtained after replanting activities. Oil palm trunks contain high moisture content also known as a sap which sometimes could be as high as 500% (Husin *et al*., 1985). This biomass composed a plenteous amount of lignocelluloses, material with major component of starchy material and cellulose that can be converted into sugar subsequently by fermentation into ethanol. However converted starch and cellulose material into sugar are more complicated and required high energy consumption that involves high production costs compared to direct utilization of sugar which are readily available in the oil palm sap (Lin and Tanaka, 2006). Large amount of polysaccharides or fermentable sugars such as sucrose, glucose, fructose, arabinose, mannos and etc are easily found abundantly inside the oil palm sap from the extracted of these lignocelluloses. Therefore, a new method was developed to obtain a large amount of sugar, oil palm sap seem to be a potential source to fulfill this requirement.

## 1.2 Objective

The objectives of this study are:

1. To analyze the free fermentable sugar content and composition of the pressed sap samples from felled oil palm trunks at a different duration of storage, location and cultivars or clone.
2. To determine the optimum amount sugar and starch content from felled oil palm trunks based on duration of storage, location and cultivars or clone.
3. To identify the potential cultivars contain high concentration of sugar sap in oil palm trunks.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Oil palm tree

### 2.1.1 Overview of Oil Palm (*Elaies guineensis*)

The oil palm (also known as *Elaeis guineensis*) is a perennial crop originated from West Africa where is it widely used as a source of edible oil. This crop is woody monocotyledons in the family Arecaceae and the subfamily *Cocoideae*, similar grouped with coconut. The name *Eleais* is derived from Greek word *Elaion* with the meaning oil (Corley and Tinker, 2003). Figure 2 showed the oil palm tree (*Elaeis guineensis*).

Figure 2: Oil Palm Tree (*Elaeis guineensis*)

The African oil palm, *Elaeis guineensis* has been marked by Jacquin in 1973 as a first species from genus *Elaeis*. *Elaeis oleifera* was identified as a second species by Latiff (2000). His research in Advances in oil palm research book, explained the difference of this species with genus *E.guineensis* is their physical properties of the tree. Crossing species between *E.guineensis* and *E.oleifera* ultimately produce a new type of *Elaeis*, namely *Elaeis odora*. However, species from *Elaeis guineensis* has been widely introduced and commercialized until it's became one of the major important crops in South East Asia especially Malaysian and Indonesia (Hartley, 1988).

In 1848, four seedlings from this plant have been brought from two different places: Amsterdam and Mauritius to the Bogor Indonesia as an ornamental plant and spread around Sumatera in 1853 and 1856. This oil palm trees has been planted in some estate in Deli, Sumatera which gave a name to the Deli palm cultivar. In Malaysia, cultivated of oil palm tree has begun in the early 19$^{th}$ century. It has been introduced into Malaysia through the planting of Deli origin also known as Deli dura from Sumatera in the Rantau Panjang, Selangor (Corley and Tinker, 2003; Latiff, 2000). Enhancement of Research and Development (R & D) in Malaysia has brought these types of palms into a first commercial oil palm estate in Tennamaram estate, Selangor in 1917. In 1950's, plantation of oil palm tree has been commercialized and become a new interest due to a stability price of world market and to lessen the dependency on rubber as a main commercial crop at that time (Hartley, 1988). From 1930s to 1980s the rates of planting activities in Malaysia increase tremendously. Until now oil palm has monopolized the agriculture crop in Malaysia.

### 2.1.2 The palm oil industry in Malaysia

The palm oil industry played an important role in a development of Malaysia economy especially in the agriculture sector. Based on Malaysia Palm Oil Council (MPOC) statistical in 2009, production of oil palm, Malaysia has become second largest producer of palm oil after Indonesia, representing about 41% of a total world market. Presently, both Malaysia and Indonesia dominate over 80% of the world production of oil palm. Production of oil palm industry in Malaysia has risen extensively in recent time from 94 000 tons in year 1960 to 15 million tons in year 2005 particularly in the production of oleo-chemical, bio-fuel industries and oil and fats to fulfill the world demand in various usages. The production of oil palm during the various years of the last century in Malaysia is shown in Table 1.

Table 1: World production of oil palm

| Countries | Years (000' tonne) | | | | | |
|---|---|---|---|---|---|---|
| | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 |
| Malaysia | 2576 | 4133 | 6088 | 8123 | 10842 | 14962 |
| Indonesia | 691 | 1243 | 2413 | 4220 | 7050 | 14070 |
| Ivory coast | 182 | - | 270 | 285 | 278 | 260 |
| Nigeria | 433 | 386 | 580 | 660 | 740 | 800 |
| Columbia | 74 | - | 226 | 388 | 524 | 661 |
| Papua New Guinea | 35 | - | 145 | 223 | 336 | 310 |
| Thailand | 13 | - | 232 | 355 | 524 | 685 |
| Brazil | 12 | 29 | 66 | 75 | 108 | 160 |
| Others | 875 | 1041 | 1000 | 5994 | 5191 | 1826 |
| Total | 4891 | 6832 | 11020 | 20322 | 25594 | 33733 |

Oil world (2010); MPOB (2010)

Based on the above statistic estimation on palm oil plantation area by MPOB (2010), it is postulate there will be about 152,133 hectares of oil palm that will be ready to be replanted in year 2010 and about 140 trees of oil palm in each hectare. This will represent about 21.2 millions of oil palm trees. For each tree, it is estimated to be around 1 tonne of oil palm trunk biomass available which is carried out about 21.2 million tonnes of oil palm trunk biomass available each year that are ready to be used. Therefore, the promising and sustainable amount supplies of this biomass for each year available as long as there are new replantations of oil palm are made. Figure 3 showed the planting oil palm area in Malaysia in the decades of the last century.

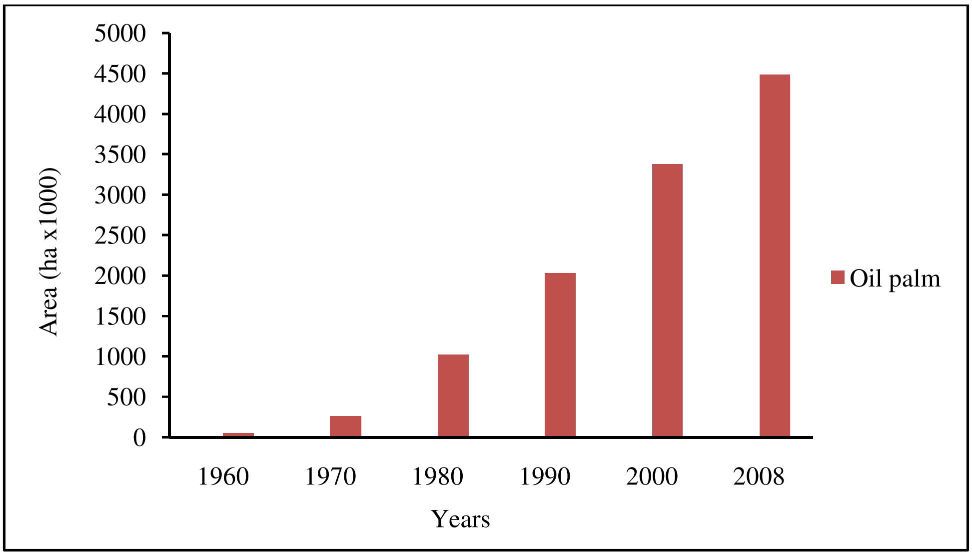


Figure 3: Area of oil palm planting in the decades of the last century (MPOB, 2000; MPOB, 2010).

The availability and consistency of supply of palm oil has been a main factor in stabilizing global market. At the end of 2007, areas under oil palm has climbed up from 54 000 hectares in year 1960 to 4.24 million hectares. Oil palm was occupied approximately about 60% of agriculture area in Malaysia and its led to a major commercial planting in Malaysia replaced other agriculture crop such a rubber, coconut and cocoa (Basiron, 2008; Basiron, 2002).

## 2.2 Breeding of oil palm

### 2.2.1 Development of breeding program

The early oil palm breeding program in Malaysia was started by using Deli Dura seedling discovered by Jack and Jagoe in 1930's which is taken from Bogor Botanical Garden palms (Hartley, 1988). This breeding material was introduced to the Department of Agriculture (DOA) in Serdang and Elmina Estate on 1920’s. Due to limited number of parents, many breeding program was established with the objective to improve the high yield bunch with good quality and high oil yield. Besides, the pest and disease tolerance, suitability of seeding to growth well in climate and soil in Malaysia was considered as a serious factor during selection breeding program (Corley and Tinker, 2003). Figure 4 showed the history and development of Deli dura varieties in Indonesia and Malaysia until 1979.

Extension from these programs, the oil palm material from Indonesia and Africa has been brought by United Plantations Berhad (UPB) in 1927’s. Oil palm of Malaya (OPM) of Kumpulan Guthrie Berhad (Guthrie) on Ulu Remis and Eleais Estates and Societe Financiere de Caoutchouces (Socfin) on Johore Labis Estate were established in 1933's. Further, more research organization such Palm Oil Research Institute of Malaysia (PORIM) currently known as Malaysian Palm Oil Board (MPOB) and Malaysian Agricultural Research and Development Institute (MARDI) has been established exclusively in seeking genetic, creation new breeding and seeding by intercrossing seedling from various origin (Khushairi and Rajanaidu, 2000).

The research on palm oil breeding has carried out since 1960s. The research on *Dura* variety with the poor quality and low oil yield in the range of 12-16% has comes out by exploiting this cultivars with Pisifera variety to produced Tenera palm, which result in increased in oil yield up to 25%. From 1960 to 1970, Tenera breeding was planted widely and undertaken the commercial planting of Deli dura material (Hartley, 1988; Kushairi and Rajanaidu, 2000).

Collaborative research centers in Malaysia under 'International Experiment' such as Cooperative Breeding Scheme (CBS) and Sabah Breeding Schemes or programme (SBS) with international research institute, successfully create a new breeding seedling; E206 Dumpy dura (under SBS programme). By 1963, more local research institute such Guthrie, Golden Hope, Dunlop and Pamol involved in the formation of Oil Palm Genetic Laboratory (OPGL) with the same objective to enhance oil palm seeding and breeding quality though research activities. Extensive breeding program was developed in 1964 at the Sabah Department of Agriculture in Ulu Dusun that involve in a large collection of oil palm material from various research centers from

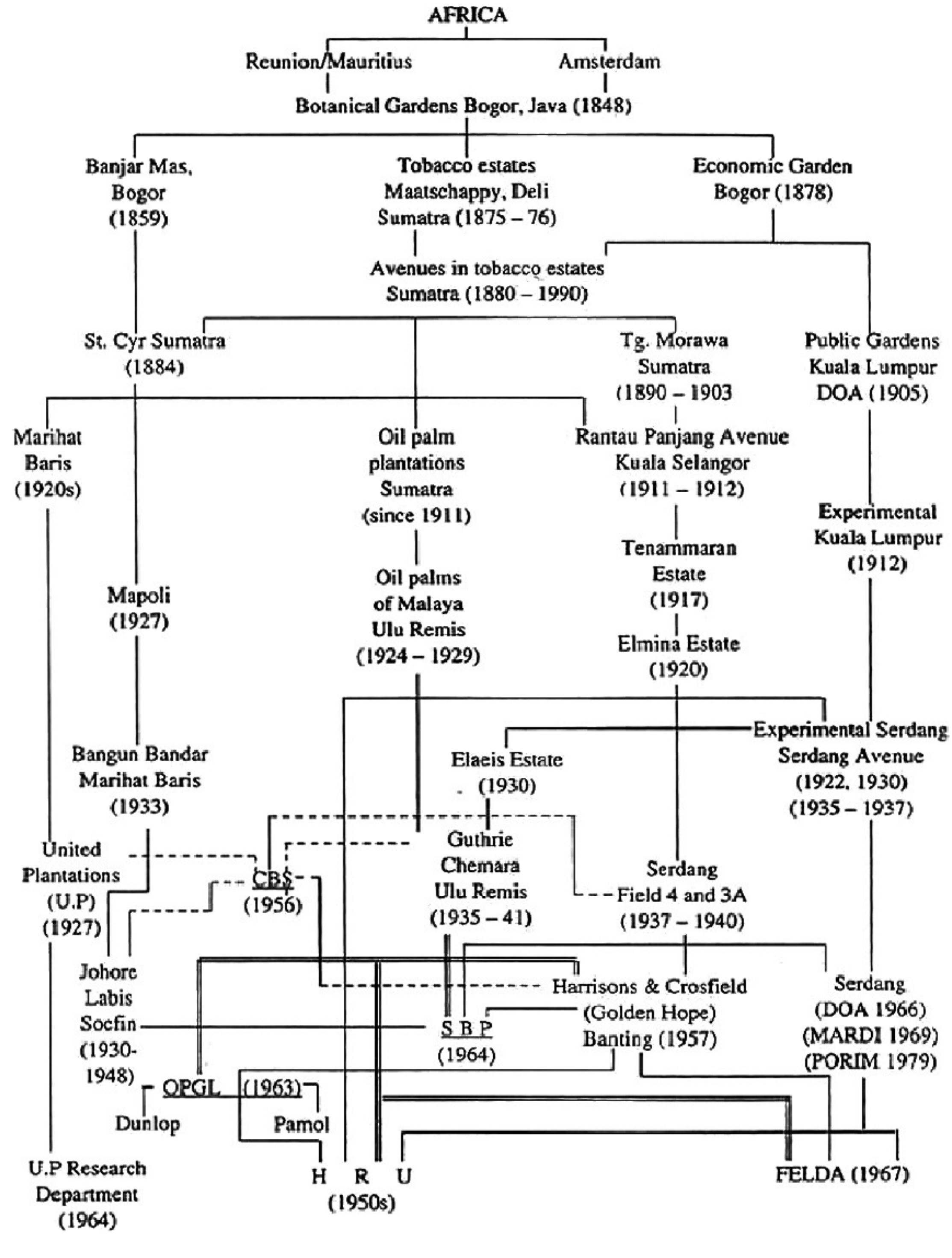


Figure 4: History and development of Deli dura in Indonesia and Malaysia till 1979. (Kushairi and Rajanaidu, 2000).

Malaysia and Institute for Oil Palm Research (NIFOR) for further research and development of oil palm cultivation in the country. Many hybrid breeding has been produced by breeding program such an AVROS, Yangambi, Dumpy and etc, to fulfil the market satisfaction (Corley and Hardon, 1976; Hartley, 1988).

### 2.2.2 Selected oil palm breeding

Four hybrid breeding, which are Dura x Pisifera mix, Dumpy x Yangambi x AVROS, Deli Dura x Yangambi (D3D x L236T) and Deli Dura x Pisifera x H&C randomly, selected from species *Elaeis guineensis*. Early observation revealed the presence of these cultivars; Dura, Pisfera, Dumpy and Tenera, could be differentiate by outer appearance of the fruit. Hartley (1988) found that the classification of the varieties is related to an anatomy of the palm fruit. The Dura palm consist thick pericarp or exocarp, 2 and 8 mm, thick endocarp (shell) and generally large kernel. The Pisfera has a fruit with thick mesocarp, less endocarp (shell) and small kernel. The Tenera is the product of the cross of Pisfera and Dura. It contains thick mesocarp, thin endocarp and middle sized of kernel. Dumpy palm is a short stem found on Deli plantation at Elimina. The progeny of Dumpy was selected based on the satisfaction crossing outcome, high yielding short stem palm. However due to a low percentage of clean fruit per bunch, this Dumpy palms seed were crosses among different oil palm seedling; Deli Dura, Pisifera or Tenera to obtain a high percentage of fruit bunch and produced a intermediate tall palm stem (Owolalarafe *et al.*, 2007; Kushairi and Rajanaidu, 2000; Opeke, 1982; Basiron *et al.*, 2000). Research in crossing among selected varieties look very promising especially in term of yield and quality of fruit. The new genes such Yangambi, AVROS, Chemara, H&C and etc is produced from the hybridizations between varieties; Dura x Pisifera, Dura x Tenera and Dura x Dura. Moreover, each and every type of these new genes will present different characters which affect the final outcome (Ascenso, 1965; Hartley, 1988). Figure 5 showed the varieties of palm oil fruit from species *Elaeis guineensis*.


Figure 5: The varieties of palm oil fruit from species *Elaeis guineensis*; Dura, Pisifera and Tenera (Sime Darby, 2010).

Breeding program has been introduced to Division of Agriculture, Malaysia with the main objective to increase the oil yield. The mutation breeding play an important role for further use especially in fuel, nutritional products, food, nutraceuticals and pharmaceuticals industry. The objective of these breeding programs are; 1. Increased the oil yield, 2. Enhanced of oil quality, 3. Produced short palms tree, 4. Resistance to desease, 5. Physiological traits (bunch index, total dry matter and bunch dry matter), 6. Exploitation of GxE interaction (Rajainaidu *et al*., 2000)

### 2.3 Oil Palm Biomass

#### 2.3.1 Oil palm trunks

Oil palm industries generate a large amount of oil palm biomass throughout the harvesting and processing activities. As shown in Figure 6, the massive amount oil palm trunks biomass generated after harvesting activities.

Figure 6: The oil palm trunks biomass after harvesting activities.

In 2005, Malaysia alone produced more than 30 million of oil palm biomass includes empty fruit bunch, palm kernel, shells, front and palms trunks that remaining after processing activities. Improper management of this biomass could create serious environmental problems. The oil palm trees have an average economic life span approximately 20 and 25 years depending on the economically harvestable height and non productivity of oil palm fruits. Mature oil palms tree can grow up to 20 feet in height. Oil palm typically is removed from production when they reach 25 feet due to a difficulty in harvesting. Oil is the main commercial product of the oil palm, however it just contain 10% from the total oil palm biomass while the rest is remaining as a residue (Husin, 2000; Lim *et al*., 1997).

Traditionally, during harvesting activities, the old and rejected tree was felled. The tree trunks were being burned on the plantation or mulch before being left on the ground as a natural fertilizer to reduce waste, while frond part are left rotting between the rows of palm trees, mainly for soil conservation, erosion control and ultimately the long-term benefit of nutrient recycling. However, it will cause significant losses of organic material and contribute to an environment problem such air and water pollution (Suhaimi and Ong, 2001). Likewise empty fruit bunch, after the oil and kernel have been extracted the fibre from the fruit bunches have been used as a main source of solid combustion to generate power at the mills. However all these afford to manage this biomass still not enough and most of them have no practical way to utilize thus it has become troublesome waste (Balat *et al*., 2008).

Manufacturing using oil palm biomass as raw material was envisaged a long time ago. Research and development (R&D) program on oil palm trunks was started 20 years ago and it has opened a great opportunity to utilize this biomass into value added product. The product from this residue offered the best prospect as a raw material and could be commercialize that is provided additional revenue to an industry. Through several research work and manipulating the product to enhance the quality, the oil palm trunk successfully could be use to substitute or partially used in the plywood manufacturing and production of panel product such as particleboard, cement board, medium density fiberboard (MDF) and etc. (Chew and Bahtia, 2008).

Nowadays, Malaysia research has stepped up to another level by convert every part of this biomass into bioethanol product. Exploitation on biomass fuel effectively improves the quality and yet it can be used to generate power plant. As a major part of biomass, oil palm trunks show an excellent potential to replace the other natural source in production of ethanol for the future.

### 2.3.2 Growth and morphology of oil palm tree

Oil palm or *Elaeis guineensis jacq*. is one of the palmae families. It is single stem plant and may reach to a length of 20 m to 30 m tall. This palm is growing well and produces higher bunch production at a tropical climate like Malaysia which is provide plenty of sunshine with the average annual of rainfall about 2000 mm and yearly temperatures ranging from 25 to 28°C. Soil also one of the important factors that would affect the growth and production of oil palm. Mostly, the hilly soil with the suitability type of soil would give the satisfactory yield and extension of the stem due to the exposure to a sun (Hartley, 1988).

Palm oil is monoecious plants which grows and produce inflorescences either male or female or sometimes for the young palm, during the transitional stage between male and female cycle the hermaphrodite may occur (Latiff, 2000). The inflorescences grow in the left axils and for both sexes is a compound spadix with 100 to 200 branches, initially enclosed in a spathe or bract that splits 2 weeks prior to anthesis. There are several studies by Owolalarafe *et al*., (2007), Kushairi and Rajanaidu (2000), Hartley (1988) and etc. that have been made to identify the varieties of the oil palm tree. The classification of oil palm tree into their species is based on characters of fruit (Tomlinson, 1961; Corley and Tinker, 2003).

#### 2.3.2.1 Anatomy of Oil Palm trunk

The oil palm tree is a monocotyledon species of flowering plants. This tropical plant is an unbranched plant and with the single stem. A mature stem growth is an erect and sheltered by persistent frond bases. The stem supports a crown of fronds and at age 12 and 15 years of ages, it may carry 25 to 40 fronds. The fronds contain leaflets which is pinnate with dark green leaf, ranging about 3 to 5 cm. Because the oil palm tree is a non wood tree, it does not comprise cambium, secondary growth, annual rings, ray cells, sap wood and heart wood or branches and knot (Bunting *et al*., 1934; Killman and Lim, 1985). From the cross section area, the oil palm trunks could be divided into 3 parts; inner, middle and peripheral part as been shown in Figure 7.

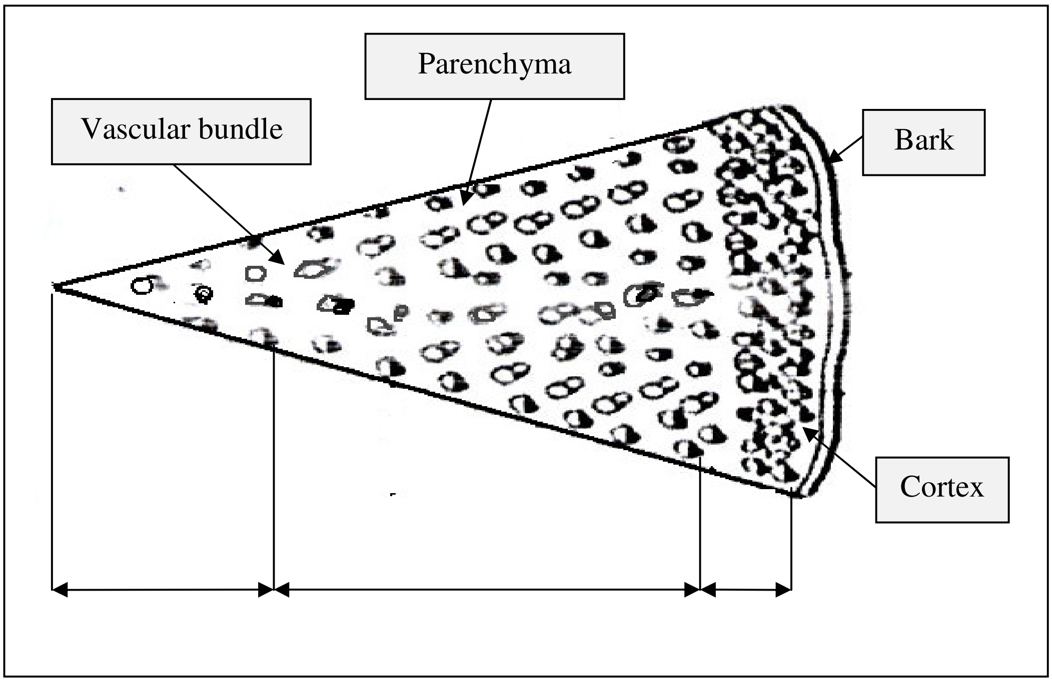


Figure 7: Cross section of oil palm trunks (Killman and Lim, 1985).

The main function of the trunks as a mechanical support to a tree and storage organ which is certainly contains an enormous amount of carbohydrate. The oil palm trunks consist of a parenchymatous tissue, vascular bundle and single strands are shown in Figure 7. The vascular bundle functionally use as a transporter of nutrient and water from the roots to a crown and photosynthesis product from fronds to a downwards. Often, each of vascular bundles consists of single strands fiber, phloem cells xylem and parenchyma cells. Commonly, xylem cells contain two wide vessels and sheltered by parenchyma cells. The phloem cells present in single strand form between xylem and fibre strands. The fibrous sheathed exist abundantly in peripheral part, thus it give the mechanical strength to the palm trunks (Tomlinson, 1961; Janick, and Paull, 2008)