EFFECTS OF STORAGE TIME AND TREE HEIGHT ON SUGAR AND STARCH COMPOSITIONS OF OIL PALM TRUNK BIOMASS

by

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KESAN MASA PENYIMPANAN DAN KETINGGIAN POKOK KE ATAS KOMPOSISI GULA DAN KANJI BAHAGIAN BIOJISIM BATANG KELAPA SAWIT

ABSTRAK

Kesan masa penyimpanan dan ketinggian pokok ke atas komposisi gula dan kanji bahagian biojisim batang kelapa sawit yang berusia 25 tahun daripada tiga batang telah dikaji. Sampel yang berdasarkan ketinggian pokok telah dibahagikan kepada 4 ketinggian berlainan iaitu bahagian atas (TOP), bahagian tengah atas (MDT), bahagian tengah bawah (MDB), bahagian bawah (BOT) untuk setiap 3 batang kelapa sawit. Batang kelapa sawit telah disimpan selama 120 hari dan dipotong kepada disk mengikut 0, 1, 3, 7, 15, 30, 60, 90, 120 hari penyimpanan. Disk tersebut dibahagikan kepada 3 bahagian iaitu, bahagian dalam (A), bahagian tengah (B) dan bahagian luar (C). Kemudian, sampel diperah menggunakan mesin tekan untuk mendapatkan sap. Analisis Kromatografi gas (GC) menunjukkan peningkatan kandungan glukosa di dalam sap dan kajian diteruskan dengan menggunakan HPLC. Analisis oleh HPLC menunjukkan wujudnya komposisi gula iaitu glukosa, fruktosa, galaktosa, sukrosa dan inositol. Jumlah maksimum gula yang ditemui adalah pada hari ke-60 masa penyimpanan. Ketinggian pokok sawit pula menunjukkan perubahan oleh setiap komposisi gula. Bahagian teras pokok telah menunjukkan kandungan sap dan juga kandungan gula yang paling tinggi di dalam pokok kelapa sawit, manakala glukosa merupakan gula utama di dalam sap. Menurut kaedah Humprey dan Kelly, ia menunjukkan bahawa kandungan kanji menurun mengikut masa penyimpanan. Kandungan kanji yang lebih tinggi dilihat pada bahagian atas berbanding bahagian

bawah pokok kelapa. Mikroskopi Elektron Imbasan (SEM) menunjukkan taburan kanji di dalam batang.

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EFFECTS OF STORAGE TIME AND TREE HEIGHT ON SUGAR AND STARCH COMPOSITIONS OF OIL PALM TRUNK BIOMASS

ABSTRACT

Effects of storage time and height of trees on sugar and starch compositions of the oil palm biomass at age 25 years of three logs were studied. Each log was divided into 4 different height portions, which were top part (TOP), middle of top part (MDT), middle of bottom part (MDB) and bottom part (BOT). The samples were stored for 120 day and within this period, the samples were cut into the disc on 0, 1st, 3rd, 7th, 15th, 30th, 60th, 90th and 120th day. Each disc was divided into 3 cross-sectional segments, which were inner part (A), middle part (B) and outer part (C). Then, these discs were squeezed with machine press to obtain the sap of the oil palm trunk. Gas Chromatographic (GC) analysis showed the increasing glucose content in the sap with the increasing storage time. The HPLC analysis indicated the presence of glucose, fructose, galactose, sucrose and inositol in OPT sap. The maximum amount of sugar was found on the 60th day of storage. Whereas no well-defined trend in sugar content was observed with OPT height. The highest liquid and sugar content was discovered in the core part with glucose as the major sugar in the sap. Starch content by Humprey and Kelly method showed decreasing amount with the prolonged storage time. Higher starch content was the upper portions of the OPT compared to the bottom part of the trees. This coincides with the distribution of starch granules observed from Scanning Electron Microscopy (SEM) analysis of the trunk.

1.0 INTRODUCTION

1.1 General

Oil palm tree (*Elaeis Guineensis*) was introduced in Malaysia on 1917, and it is one of the most prestigious commercial and marketable crops. Known as the golden crop, it has positioned Malaysia as the leading nation in oil palm production. With the increasing trend of worlds demand for oils and fats, the oil palm industry has led to rapid growth of oil palm plantation area in the country.

In the oil palm industry, it mainly focuses on the production of oil. However, this industry also produced the by-products and left over biomass. Currently research and development activities in Malaysia are not only focusing on the production of oil, but also on the utilization of industrial waste from the production of oil and on the biomass produced from this industry. This includes empty fruit bunches (EFB), oil palm fronds (OPF) and oil palm trunks (OPT). The biomass is available throughout the year as empty fruit bunches (EFB) and pruned fronds. Besides that plantation also produce large quantities of trunks and fronds (Basiron et al., 2000).

In the oil palm industry also, the oil palm biomass has an enormous potential to be converted into high value-added and useful income-generating products such as ethanol. Recently, the ethanol production from oil palm biomass has become of great interest. One of the ways of getting ethanol is by fermentation process that converts sugar into ethanol. For optimization of the process, the amount of sugar in the oil palm trunk must be investigated.

Besides sugar, the oil palm tree also contains starch which is one of the main components in the oil palm trunk. Starch is very important natural product, occurring in the leaves of green plants, fruits, seeds, stems, roots, and tubers. It serves as the chemical storage form of energy. Naturally, the energy stored in the palm is used for its life processes, especially for flower and fruit production. When the energy stored in the starch is needed, it will be converted to simple sugar again and then transported in the sap to where it will be needed (Martin, 2007). Starch is used widely in food industries as a chemical storage of energy. It has been used to thicken food such as sauces. In other industries, starch is widely used in the manufacturing of adhesives, paper and textiles (Robyt, 2008).

Biomass-based raw materials oil palm industry also can be used for fermentation. Carbon source is the one of the variety for fermentation raw material and feedstock which available for industrial fermentations to bio-products and bio-fuels. In the industrial fermentations, carbohydrates from sugar or starch plants are the main fermentable sources. Nowadays, the use of biomass for fermentation has been increasing in recent years. The increasing demand on this raw material for fermentation will make agriculture provide high quality and cheaper feedstock in the future (Peters, 2007). The various raw materials used in the manufacture of ethanol via fermentation are easily classified into three main types of raw materials such as sugars, starches, and cellulose materials. For starches, it will be hydrolyzed to fermentable sugars by the enzymes from malt or molds. Once simple sugars are formed, enzymes from microorganisms can easily ferment them to ethanol (Yan Lin, 2006). Ethanol can be used as a preservative to standard motor fuels without modified to the infrastructure or vehicles (Bandi and Specht, 2006).

This study investigated the effect of storage time and height on some chemical composition of oil palm trunk. From this, amount of sugar can be determined during storage and based on height of the oil palm trunk. Also, in this research the oil palm trunk was investigated for its starch content after the storage for a specified time. This is essential to understand the possibility of storing oil palm trunk without affecting the quality and quantity of starch. At the same time, investigation of the starch content and chemical compositions based on height was also conducted in order to understand the effect of starch based on height.

1.2 Background research

In this research, the effect of storage time and height on some chemical composition of oil palm trunk was investigated. The amount of sugar during storage and based on height of the oil palm trunk were determined. Oil palm tree has an economic life span for about 25 years. A large quantity of cellulosic raw material is generated in the form of felled trunks and fronds during replanting and it was still underutilized. In Malaysia, the oil palm plantation covering an area of approximately 3.8 million hectares will generate large quality of residues in the form of trunks, fronds and empty fruit brunches (EFB) (Yacob, 1998).

In storage study showed that after period time, the logs of wood or OPT log will be attacked by fungi. Because of that, the chemical compositions of wood stored also were showed some changes during the storage period analysis. Especially in sugars composition, it was converted or changed to the other acids composition or structure (Winterhalter et al., 2003) in storage content. The compositions were converted to starch in the trunks for storage as energy. When the stored starch is needed as an energy, it will be converted to simple sugars again and then transported in the sap form to everywhere the energy needed (Johannesen, 1991).

The sap contains 5 to 15 percent sugars and can be fermented. Fermented of sap produces alcohol, and then acetic acid called vinegar. The fiery arrack can be obtain from distilled the alcoholic toddy which much prized more than hard liquor (Martin, 2007). Alcohol also known as a liquor is a source of energy and it commonly used as a transportation fuel, heating, cooking and lighting. There are two kinds of common alcohols, ethanol (grain alcohol) and methanol (wood alcohol). In short, both ethanol and methanol could be produced in a variety of ways; from the organic compounds of fossil fuels or the sugars of natural plant products (Johannesen, 1991).

In the related research for energy, the scientists in United States have found a new method for new energy by transformed sugar into a liquid transportation fuel which has a 40 percent greater energy density than ethanol. A better way to make a chemical intermediate called HMF (hydroxymethylfurfural) from fructose - fruit sugar. HMF can be converted into plastics, diesel-fuel additive, or even diesel fuel itself. The new process goes beyond making fuel from plants to make industrial chemicals from plants (Anonymous, 2008).

1.3 Hypothesis

The hypotheses of this study are:

1) The sugar content is expected to be influenced by the storage time
2) The sugar content is expected to be influenced by the height of the trunk
3) The starch content is expected to be influenced by the storage time
4) The starch content is expected to be influenced by the height of the trunk

1.3 Objectives

1. To determine the effect of storage time on sugar and starch contents in oil palm trunk.

2. To determine the effect of tree height on sugar and starch content in oil palm trunk.

3. To study the amount and type of the free sugar contains in pressed sap trunk by storage and tree height of the oil palm trunk.

4. To study the amount and type of the free sugar contains in the section of inner part, middle part and outer part of the trunk based on storage and tree height of the oil palm trunk.

1.0 Literature Reviews

2.1 Oil Palm tree

2.1.1 Historical background of oil palm

Oil palm (*Elaeis Guineensis*) as shown in Figure 2.0 is tropical permanent species in the order Arecales of the family Aracaceae (Dransfield et al., 2005). At the adult age, this arborescent monocotyledon shows the typical morphology of palms. On average, it produces two leaves per month which is growth by a single terminal meristem. The root system is made of a large number of fasciculate adventitious roots. Oil palm grows preferentially in rich and temporarily damp mud soils (Corley and Tinker, 2003). It can reach 30 meters in height, with a leaf crown 10 to 16 meters in diameter, and so it requires a large soil area to avoid competition for light and nutrients. The oil palm is a temporal dioeciously species (Cruden, 1988) which displays alternate male and female flowering cycles throughout its life. By using light and scanning electron microscopy (Adam et al., 2005) recently described inflorescence and flower development in oil palm from the beginning of the inflorescence meristem to flower maturity. Industrial exploitation of oil palm commenced at the beginning of the twentieth century, initially in Southeast Asia, later along the Gulf of Guinea in Africa and then in tropical America (Adam et al., 2005).

During the latter half of the twentieth century, its development area extended into the Americas, mainly in the Amazon basin and the Pacific coast of Colombia and Costa Rica. In Southeast Asia Intensive planting also occurred and, to a lesser extent, in West Africa. The global area planted with oil palm now reaches 11×10^6 ha within the humid inter-tropical belt, where around 70% of the plantations are exploited by smallholders. The originality of the oil palm resides in the fact that the fruit is the source of both oil palms which extracted from the mesocarp and palm kernel oil. Oil palm is the most productive of all oil crops (MPOB, 2010).

Figure 2.0: Oil palm (*Elaeis Guineensis*)

2.1.2Current view of oil palm in Malaysia

The oil palm is a tropical palm tree that can be developed easily in Malaysia. The oil palm tree in Malaysia was actually originated from West Africa where it was growing wild and afterward developed into an agricultural yield. The first commercial oil palm estate in Malaysia was set up in 1917 at Tennamaran Estate, Selangor (Tate, 1996).The development of the palm oil industry begin in smallholder plots and farms and was in the beginning used for farmer's domestic purposes or sold locally. Most of this increase can be attributed to production in Malaysia and Indonesia, and some to smaller Asian producers (Malaysian Palm Oil Board Statistic, 2009).

Malaysia becomes one of the largest producer and exporter of palm oil in the world as the production of the oil palm shown in the Table 2.0 as the increasing amount of oil palm production at 2010 to 2011 (MPOC, 2011). Month by month, the production of oil palm showed an increasing of the amount. For 2010, the production from January till Jun was 7,976,853 tonnes while for 2011, the production increased to 8,593,755 tonnes for January till Jun. The total production for 2010 was 16,993,423 tonnes which is predicted to be more in 2011.

Table 2.0: The oil palm production, 2010 to Currently (MPOC, 2011)

	Production	
	2010	2011
Jan	1,321,304	1,057,961
Feb	1,156,814	1,094,339
Mar	1,387,234	1,416,440
Apr	1,306,228	1,529,985
May	1,385,424	1,741,827
Jun	1,419,849	1,753,203
Jul	1,518,753	
Aug	1,606,563	
Sep	1,562,912	
Oct	1,636,560	
Nov	1,459,030	
Dec	1,232,752	
Jan-Jun	7,976,853	8,593,755
Jan-Dec	16,993,423	

Table 2.1 shown the total export of oil palm product in Malaysia has increased from year 2009 to 2010. As in the table 11, the total exports of oil palm products, including of palm oil, palm kernel oil, palm kernel cake, oleochemicals, biodiesel and finished products increased from 22.43 million tonnes in 2009 to 23.06 million tonnes in 2010 because of higher export prices of oil palm products.

Table 2.1: The oil palm production, 2009 to 2010 (MPOB, 2010)

	2009	2010
palm oil	15,880,744	16,664,068
palm kernel oil	1,117,478	1,163,586
palm kernel cake	2,381,571	2,443,383
Oleochemicals	2,174,667	2,223,668
Biodiesel	227,457	89,609
Finished product	580,233	409,373
Other palm product	64,898	66,343
total exports (tonnes)	22,427,050	23,060,031

On other hand, The demand for world vegetable oil increased which give Malaysia a big opportunity to become of the major contributors of world vegetable oil in the next future and oil palm just overtake the title of the most important vegetable oil source after year of 2000 (Sambanthamurthi et al., 2000).Besides that, Malaysian oil palm can also be used to produce many other downstream oleo-chemical products such as soap, palm fatty acids, palm methyl esters and many more. This confirms that the utilization of oil palm as a source of energy is rising. Figure 2.2 shows that Southeast Asia has greater productivity than the others major producer countries. There are a few factors which led to the expansion of the harvesting area in Southeast Asia. One of the factors was increase in the consumption of dietary oils and fats in China and India which give strengthened push to the market prices of palm oil a kernel oil. This has encouraged investor to develop plantations on the large areas of suitable land found in Peninsular Malaysia and certain parts belong to Indonesia (Ernst and Thomas, 1999).

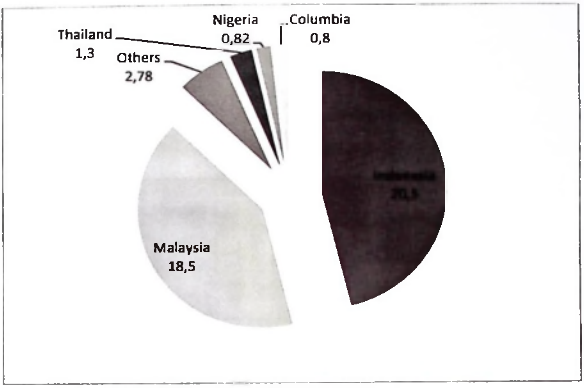

Figure 2.2: World major producers of palm oil 2009/2010 ('000 tonnes)(Forest Agriculture Service 2009)

The Oil palm cultivation and processing, like other agricultural and industrial activities, are regulated by environmental legislation aimed at conserving and protecting the natural environment. There rules and regulations play significant role in minimizing the degradation of the soil, water and atmospheric environment. Oil palm industry is currently producing the largest amount of biomass in Malaysia with 85.5% of oil palm plantations in Malaysia as shown in Figure 2.3 (Shuit et al., 2009). As the second largest oil palm plantation country after Indonesia, Malaysia produces a large amount of residues due to increasing global demand for palm. With such a large area of oil palm plantations, an abundant oil palm biomass will be produced over the years due to replanting of the oil palm trees when the trees mature.

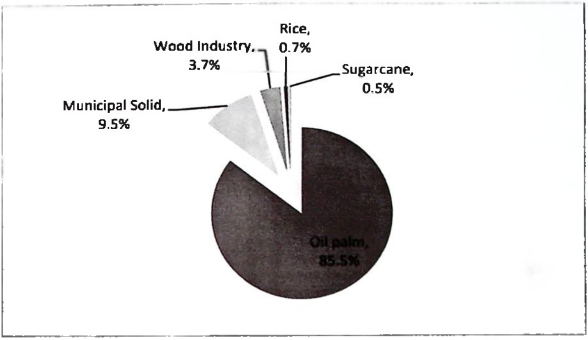

Figure 2.3: Biomass produced in Malaysia (Shuitet al.2009)

Apart from that, huge quantities of biomass by-products such as empty fruit bunch (EFB) fibers; fronds, shells, and trunk are also produced. These biomasses can be transformed into many value added product.

2.2 Potential use of biomass

Biomass is potential to be converted into the energy consumption and overall potential use of the biomass is renewable energy or renewable fuel. The biomass potential involve in fuel production. This renewable energy consumption from biomass has increased steadily over the last century as the world population has grown and more countries have become industrialized (Sun and Cheng, 2002). Those were brought biomass as an important energy carrier contributing substantially to cover demands in many parts of the world. Meanwhile, biomass resources are divided by two resources as shown in figure 2.3.1.

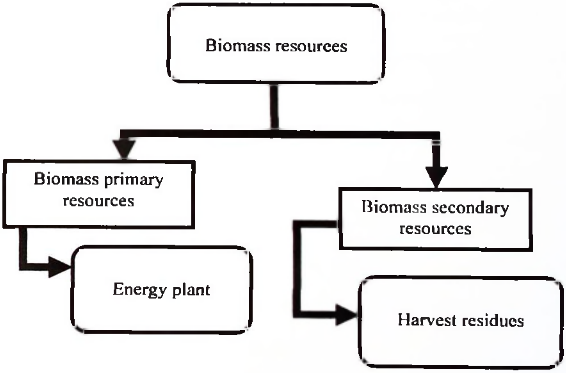

Figure 2.3.1: Biomass resources

The biomass potential can be divided into primary biomass and secondary biomass. Primary biomass is energy plants and secondary biomass is the rest biomass in the form of waste wood from forestry like harvest residues as shown in Figure 2.3.1. The best part of this biomass is it contributes a large amount of source and potentially to be regenerative energy carrier that contains concentrated carbon within. The other important advantages of this biomass are they can give diversification of the energy carriers for transportation. This because of biomass conversion or combination and the carbon dioxides (CO_2) reduction potentials that give various exploitation paths that very useful in fuel technology now day.

Biomass recourse is predicted to be an important future resource as they have potential in carbon sources combination fuel system. The combination means to be an addition of hydrogen which allows the uses all of the carbons contained were it resulting in high fuel production rate and it's very useful in fuel's technology. By using this as renewable hydrogen and CO_2, it will be possible to cover the overall fuel requirement using renewable sources in the future. The utilization of this CO_2 represents a carbon source for fuel combination which is not limited by biomass resources and that give big change to biomass recourse as the future resource (Bandi and Specht, 2006). These facts proved the title of biomass recourse as the future resource.

Above all, the biomass potentials are similar of the oil palm trunk according to secondary biomass, which is the rest biomass in the form of waste wood from forestry and industry. And that of early of my research ideal begin to select oil palm trunk as the main part of my analysis.

2.2.3Oil palm as biomass

Currently research and development activities in Malaysia are not only focusing on the production of oil, but also on the utilization of industrial waste from the production of oil and on the biomass produced from this industry where the waste biomasses are turned into renewable energy or value added products. Primary and secondary biomass can be turned into renewable energy such as bio-products, bio-fuel and bio-power. Figure 2.4 shows the scope of biomass sources initiatives.

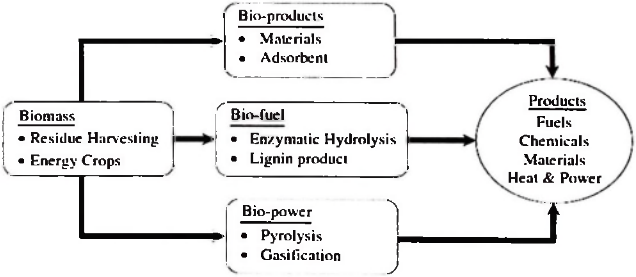

Figure 2.4: Biomass initiatives as renewable energy (Sumathi et al., 2008)

Figure 2.5 shows the study that identifies the renewable energy resource potential in the Malaysia, in Ringgit value. Based on the data above, oil palm biomass has been identified as one of the biggest resource that can be easily developed. Whereby, oil palm biomass contributes about RM 6379 million of energy annually. Although its wide use already, there is still much to be done to optimize the utilization of biomass in Malaysia.

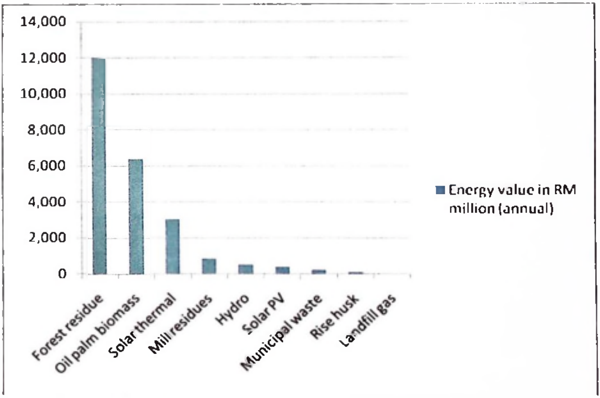

Figure 2.5: Types of renewable energy in Malaysia and its energy value (Sumathi et al., 2008)

Figure 2.6 shows types of biomass produced from oil palm tree and the quantities produced per annum in MnT. These biomasses have high potential of turning into renewable energy. Empty fruit EFB and mesocarp fiber (MF) are the highest contributor of oil palm biomass, whereby about 15.8 and 9.6 MnT have been produced per year. For the production of oil, when the palms are pruned during the harvesting of fresh fruit bunch, the Oil palm fronds are available daily throughout the year. Oil palm trunk is obtained during the re-plantation of the oil palm trees. EFB, MF and shells are collected during the pressing of sterilized fruits. (Hassan et al., 1997; Gurmit et al., 1999; Sulaiman et al., 2008)

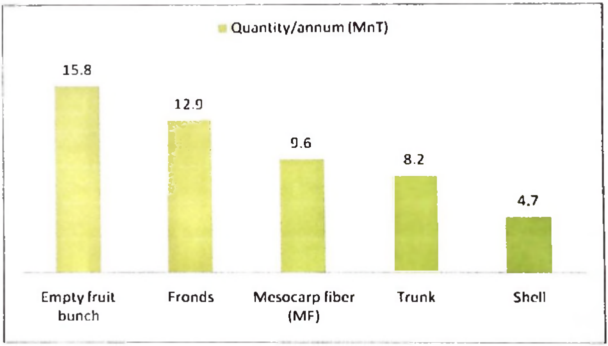

Figure 2.6: Types of biomass and quantity source (Sumathi et al., 2008)

2.2.3.1 Oil Palm trunk

The oil palm tree is a monocotyledon species (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 -15 years of ages, it may carry 25 – 40 fronds. The frond contain leaflets which is pinnate with dark green leaf, ranging about 3 - 5 centimeter. 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, 1934; Killman et al., 1985).

The main function of the oil palm stem is to provide the mechanical support to a tree and storage organ which is certainly containing an enormous amount of carbohydrate. The oil palm stem consist of parenchymatous tissue, vascular bundle and single strands. The vascular bundles within the stem functionally uses as a transporter the nutrient and water from the roots to a crown and photosynthesis product from fronds to downwards. The anatomy of the oil palm stem could be divided into three main zones; the core zone, center zone and peripheral zone as shown in Figure 2.7 (Corley, 1976).

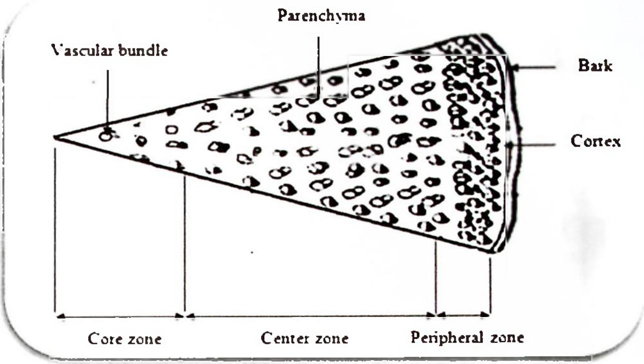

Figure 2.7: Cross section of oil palm stems (Kilman et al, 1985)

Inner zone, consist a much less congested of vascular bundles compare to central zone. According to Killman and Lim, (1985) the growth and development of oil palm stem is dependent on the overall cell division and cell enlargement in the parenchymatous tissues together with enlargement of the fiber of the vascular bundle in this zone. The central zone is a largest region which is accounts for 80 % of the total area. It's contained a large and widely scattered vascular bundles embedded in the ground parenchymatous tissue as shown in Figure 2.8.

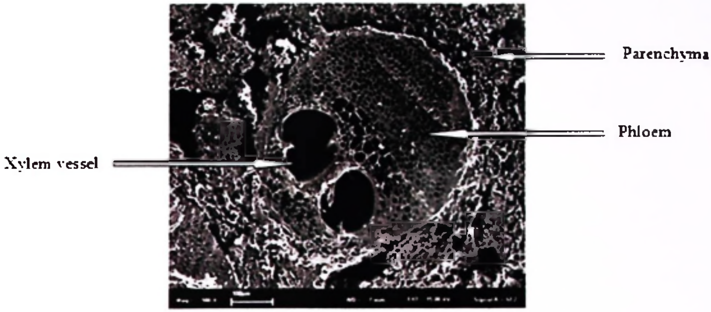

Figure 2.8: Vascular bundles with vessels at the middle section

Essentially, each of vascular bundles consists of single strands fiber, phloem cells xylem and parenchyma cells. Observation before by Tomlinson (1961) shows the ground parenchymatous cells consist of mainly thin – walled spherical cell and the walls of these parenchyma cells gently darker and thicker from pith to peripheral zone. In this zone, starch grain and silica containing cells could be revealing abundantly. For peripheral zone, it contains a narrow layer of parenchyma and crowded with vascular bundle make it rise to a sclerotic zone. Thus, it provided the main mechanical support to a palm stem. The bark is the most outer part of the palm tree. This part is a narrow cortex with a wide approximately 1.5 centimeter. Normally, there is very hard peripheral rind surround by soft central zone.

2.2.3.2 Oil Palm Sap

Oil palm sap is a water content which is retaining in the oil palm trunk. Previous study showed oil palm trunks contain high proportional of sap which includes free sugars, saccharides and polysaccharides (Henson et al., 1999). Initially, photosynthesis (via sunlight) process produced a product, and it biologically converts into high energy in form of starches, hydrolyze carbohydrate and other compound stored in storage organ. Consumption of energy by tree for its life process will cause the compound in the storage organ to convert back into sap form and supplied for every part of palm tree that needed for growing process as shown in Figure 2.8.1 (Drapcho et al., 2008).

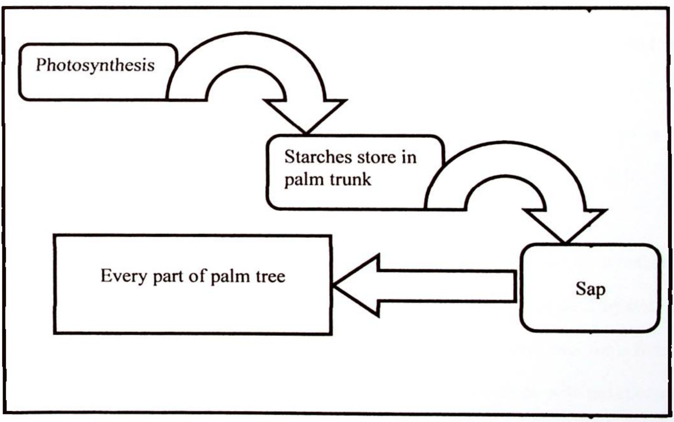

Figure 2.8.1: Energy consumption in palm tree

According to Eze and Ogan (1987) that most oil palm tree gives a sap high sugar contains. The sap is sweet and clear to yellowish color, tendency to transform into darker color due to a fermentation process. Presence of various microorganisms surrounding palm tissue especially the bacteria and yeasts accelerated the natural fermentation of sugar sap in oil palm trunk within 36 - 48 hours.

In the past, oil palm has developed many uses to fulfill commercial market demand and life pleasant due to a lower cost and produced especially in the rural area. The products derived from the oil palm trunks can be divided into many categories. Palm sap has been used widely by indigenous African and Nigeria as an alcoholic beverage. At the early, fresh palm sap has a sweet taste and refreshing because of the sugar composition inside the sap. However within 24 hours the sugar concentration decrease rapidly due to fermentation process and gave a sharp sour taste depend on temperature and duration of fermentation (Okafor, 1973; Ezeagu, 2003; Umeric, 2000; Sun et al., 2002). In addition to being a beverage, palm sap also serves as a source of sugar syrup and it used to making household vinegar in Asia (Naknean et al., 2010).

Exploitation on oil palm sap shows a potential as a raw material for bioethanol product due to high composition of sugar. Enzymatic hydrolysis and acid hydrolysis process can be used to convert sap into bioethanol to replace a fossil fuel for a future. Until now, research on palm sap into bioethanol product still carries on with the cheapest and most practical way to applied in industry.

2.3 Moisture content

Oil palm trunk is known to have high moisture content. The initial moisture content of the oil palm trunk based on oven dried weight varies from 100 and 500 per cent (Killmann and Lim, 1985).Along the trunk height and towards the central region, a gradual increase in moisture content is indicated with the outer and lower zones having far lower values than the other two zones (Lim and Khoo, 1986). The leaning in moisture content increment can be clarified by the distribution of the parenchymatous cells which retain more moisture than vascular bundles (Kohet et al., 1999).