CHARACTERIZATION OF PARENCHYMA AND VASCULAR BUNDLE OF OIL PALM TRUNK AS FUNCTION OF STORAGE TIME

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This study presents the characterization of parenchyma and vascular bundle of oil palm (*Elaeis guineensis* Jacq.) trunks harvested in Ladang Pelam, Kedah, Malaysia. Samples cut from outer, middle, and inner parts of the trunks were stored in a room at a temperature of 29°C for 0, 45, and 60 days prior to any tests. Parenchyma cells and vascular bundles from each sample were manually separated for microscopic analysis. Both light microscopy and scanning electron microscopy were employed to determine cell type, their distribution, and modification as a function of storage time. Based on the results of this work, the outer parts of the trunks had a larger amount of vascular bundles than the inner and middle parts. Moisture content of the samples from the inner part of the trunks was significantly higher than other parts. It appeared that the amount of parenchyma cells was decreased while the vascular bundle was increased in all three parts of the trunks with increased storage time.

Keywords: Oil palm trunk; Storage; Parenchyma; Vascular bundles

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INTRODUCTION

Oil palm (*Elaeis guineensis*) is one of the most important agricultural crops in Malaysia. It is originated from West Africa and introduced to South East Asia in last century (Sumathi et al. 2008). It belongs to the species *Elaeis guineensis* under the family *Palmaceae*. Oil palm has become one of the most important non-wood lignocellulosic materials for various types of products (Hashim et al. 2011).

Oil palms are monocotyledons. Vascular bundles and parenchyma tissues in oil palms are anatomically different from wood species (Tomimura 1992). Oil palm trunks have some special characteristics, including being capable of holding high moisture content (1.5 to 2.5 times the weight of the dry material), low cellulose and lignin content, and high contents of water-soluble and NaOH-soluble compounds compared to rubberwood and baggasse (He and Terashima, 1990; Husin, 1985).

A recent study on sugar accumulation in oil palm as a function of storage duration revealed that the amount of sugar in the sap increases as storage time of oil palm trunk is prolonged (Kosugi et al. 2009, 2008). It was found that the increase in sap sugar content was due to conversion that occurred to the polysaccharides in the sap. This could also be due to the conversion or fermentation of other chemical components, such as starch in the lumen, to sugar (Mansor and Ahmad 1990). Several previous studies also evaluated and determined the effect of storage time on properties of oil palm trunk (Kosugi et al. 2010; Yamada et al. 2010).

The mechanism of conversion of polysaccharides in the cell lumen of oil palm trunk to sugar has not been clearly explained. Therefore further investigation is needed for a better understanding of this phenomenon. Determination of cell composition is the prerequisite of other further investigation. Therefore, separation of the individual cells, namely vascular bundle and parenchyma as functions of duration of storage and investigation on the chemical compositions of these anatomical components were the main objectives of this work. The different chemical composition of parenchyma and vascular bundle cells would probably lead to an indication of the mechanism of polysaccharides degradation.

EXPERIMENTAL

Materials

Oil palm trunks (OPT) used in this study were harvested from a local palm oil plantation in Ladang Pelam, Kedah, Malaysia. The trunks were cut 4 feet from top middle part and 4 feet from bottom middle part, as shown in Fig. 1. The forms 8-foot lengths of log OPT trunks were stored under the shade at a temperature of 28 to 30°C and a relative humidity about 80%.

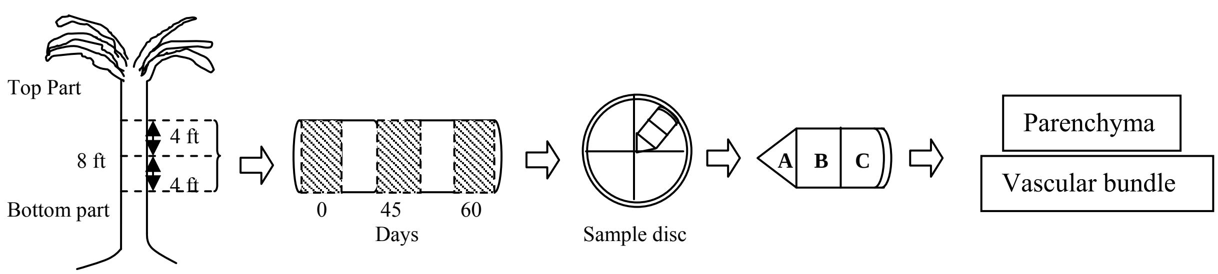


Fig. 1. Preparation of parenchyma and vascular bundles from oil palm trunk samples

Discs with 5 cm thickness were sliced from bottom of the log, and the first 5 cm from the log was trimmed before the slicing to avoid any possible contamination by fungus attack. Later the discs were divided equally into 3 parts, and each part was further divided into zone A, B and C. Zone A is the innermost part while the zone C is the outermost part of the disc. Each part was separated into 2 sections, namely parenchyma and vascular bundle, as shown in Fig. 2.

Fig. 2. Oil palm trunks samples used for experiments
a – Mixed material in different zone A (inner), B (middle) and C (outer)
b – Parenchyma, c – Vascular bundles

Methods

Moisture content of samples

The moisture content of each part before and after classification of oil palm trunks was determined by drying them at a temperature of 105^{o}C for 24 hours. The ratio of parenchyma and vascular bundles in the material was also identified. The ratio of two anatomies was determined by drying them in on oven at a temperature of 105^{o}C for 48 hours. Their weight was calculated based on oven-dried method.

To evaluate the percentage of ratio of vascular bundle and parenchyma of oil palm trunk for each part are similar from calculated and observed. For the observation the samples were cut into 2.0 cm x 2.0 cm x 2.5 cm samples. Sections were examined and photographed by using a light microscopy Model Olympus SZ40, Olympus Optical, Japan.

Scanning electron microscopy (SEM)

The morphology and the condition of fiber and parenchyma cells were examined by scanning electron microscopy (SEM). Micrographs were taken from the cross section of the samples with dimension of 0.5 cm by 0.5 cm and were coated with gold by an ion sputter coater Model Polaron SC515, Fisons Instruments, UK. A scanning electron microscope LEO Supra 50 Vp, Carl Ziess SMT, Germany was used to evaluate microstructure of the sample. The SEM analysis was also extended to determine the elemental composition of raw materials by means of energy dispersive X-ray analysis (SEM-EDXA).

Fourier transform infrared (FTIR) spectroscopy

The functional groups present in parenchyma and vascular bundle were examined by FTIR spectroscopy, Nicolet Avatar 360 (USA). Approximately 1.0 g of particles was used, and spectral outputs were recorded in the transmittance mode as a function of wave number in the range of 4000 to 400 cm^{-1}.

RESULTS AND DISCUSSION

Moisture Content of Oil Palm Trunk

Moisture content of different parts of oil palm trunk showed a great variation and range. Oil palm trunk contained higher moisture content as compared to a typical wood species. The moisture content is normally between 40% and 50%, indicating the presence of a large quantity of sap in oil palm (Kosugi et al., 2010).

Each part of oil palm trunk in the different storage showed almost the same moisture content values. The inner part of the trunk contained slightly higher level of moisture content as compared to that of the middle and outer parts during different storage time span, as can be seen in in Fig. 3. Variation of moisture content in oil palm trunk can be described by the ability of oil palm trunk to retain a large amount of water due to its anatomical structure (Killmann and Lim 1985). The different ratio of parenchyma and vascular bundle in each zone also may affect the moisture content in oil palm trunks (Husin 2000; Lim and Gan 2005), as can be seen in Fig.5.

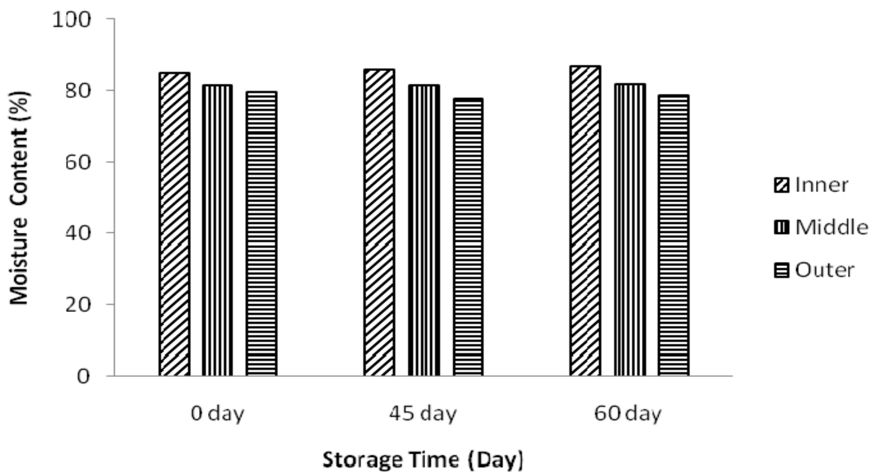


Fig. 3. Moisture content of oil palm trunk in different parts based on storage

From Fig. 4 it appears that parenchyma contribute more moisture to oil palm trunk as compared to that of vascular bundles in different parts for different storage times. This finding agrees with previous work of Yamada et al. (2010), who stated that the parenchyma hold more moisture than the vascular bundles. Therefore the difference in moisture content between the sections may be attributed by the ratio of parenchyma and vascular bundles.

Vascular bundle are less hygroscopic compared to parenchyma, naturally spongy and have high capacity in water absorption to store in the tissue cell (Killman and Lim 1985). Thus, the inner part commonly contains high moisture content followed by middle and less in outer part.

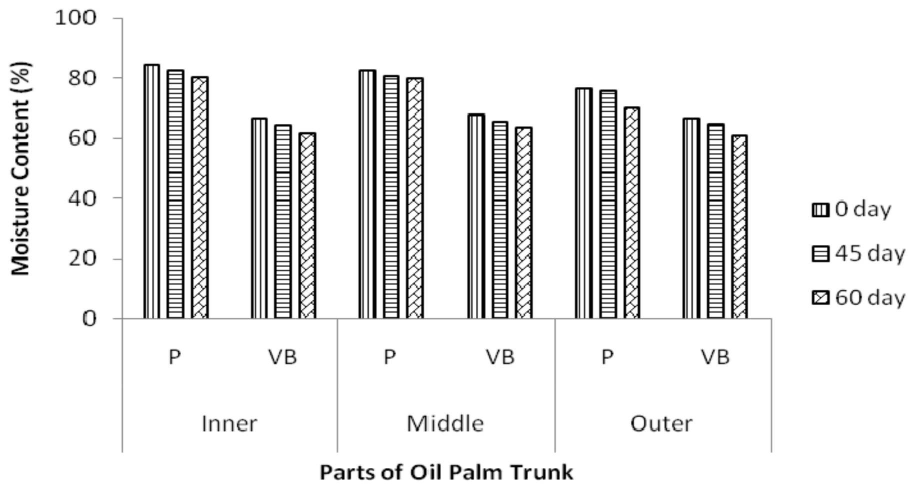


Fig. 4. Moisture content of parenchyma (P) and vascular bundle (VB) of oil palm trunk in different parts based on storage time

Percentage Ratio of Parenchyma and Vascular Bundles of Oil Palm Trunk

Percentage ratios were used to show the relationship between the two quantities A (parenchyma) and B (vascular bundle). This can also be expressed in fraction form as A/B. Fig.5 displays the percentage of parenchyma and vascular bundle of oil palm trunk stored for different time span.

Each part in oil palm trunk showed that the inner part contains higher parenchyma compared to that of middle and outer parts (Imamura 1990). With longer storage time, the parenchyma decreased in each part of the inner, middle and outer part of oil palm trunk, while the vascular bundle increased in each part similar to the findings in a previous study (Tomimura 1992). This may be attributed to the morphology and anatomy of palm species. Oil palm which is monocotyledon species does not possess any vascular cambium, so it does not increase in diameter with age. The typical feature is the distinct occurrence of the primary vascular bundles that are randomly embedded in the parenchyma group tissues. This is the key difference between oil palm and non-monocotyledon species wood (H'ng et al. 2011).

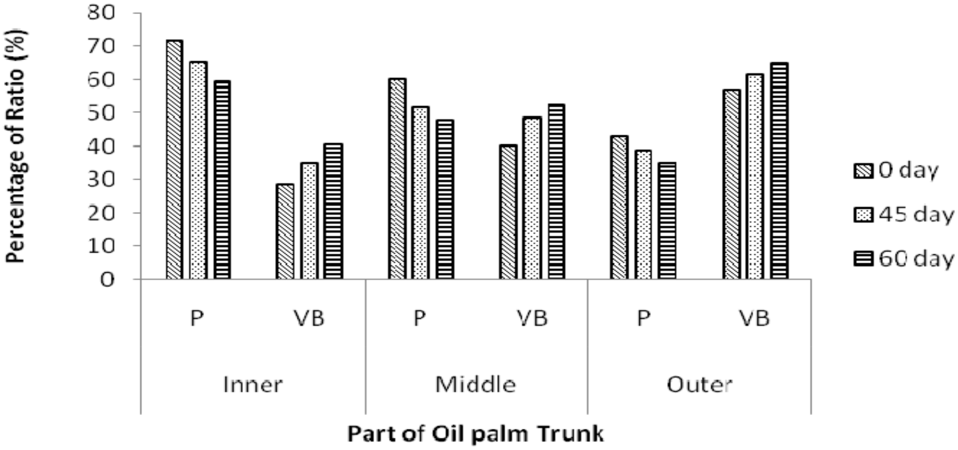


Fig. 5. Percentage of ratio of oil palm trunk

The percentage of ratio of the samples that was manually calculated revealed that the outer part (C) of oil palm trunk had more vascular bundles than the inner part of the specimen. This was supported from the microstructure evaluation as shown in Fig.6.

Microstructure Evaluation of the Samples

Based on microscopic evaluation, several cell types of the material can be distinguished. Trunk of oil palm has the basic tissues parenchyma and vascular bundles, as can be seen in Fig. 6. The outer part of the samples contained higher vascular bundles as compared to that of middle and outer parts. The parenchyma decreased in each part of the inner (a), middle (b), and outer (c) part of oil palm trunk, while the vascular bundle increased of each section as function of storage time.

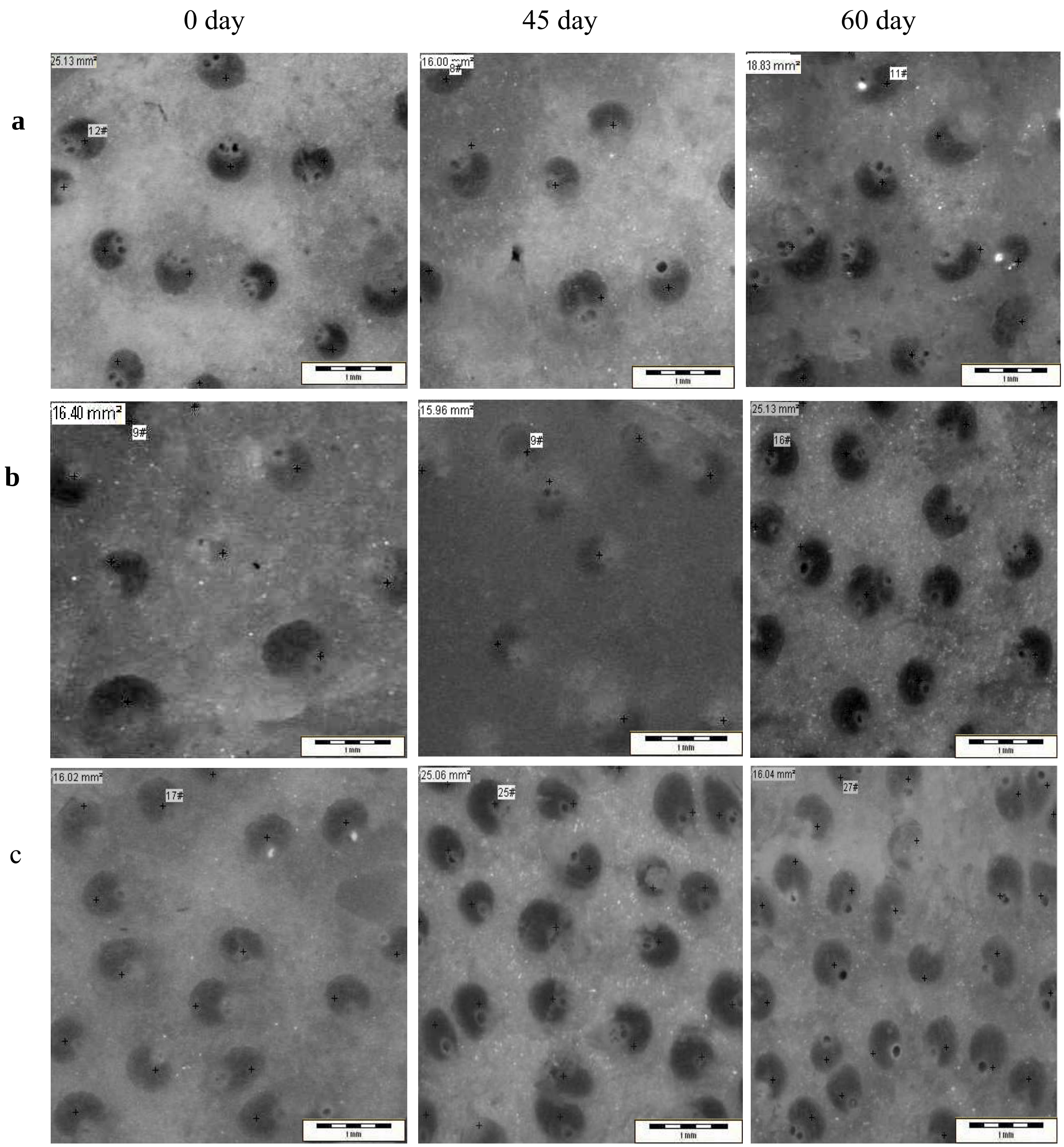


Fig. 6. Microscopic structure of different parts of oil palm trunk: (a) inner,(b) middle, (c) outer

Table 1. Percentage of Ratio of Oil Palm Trunk Using Image Analyzer

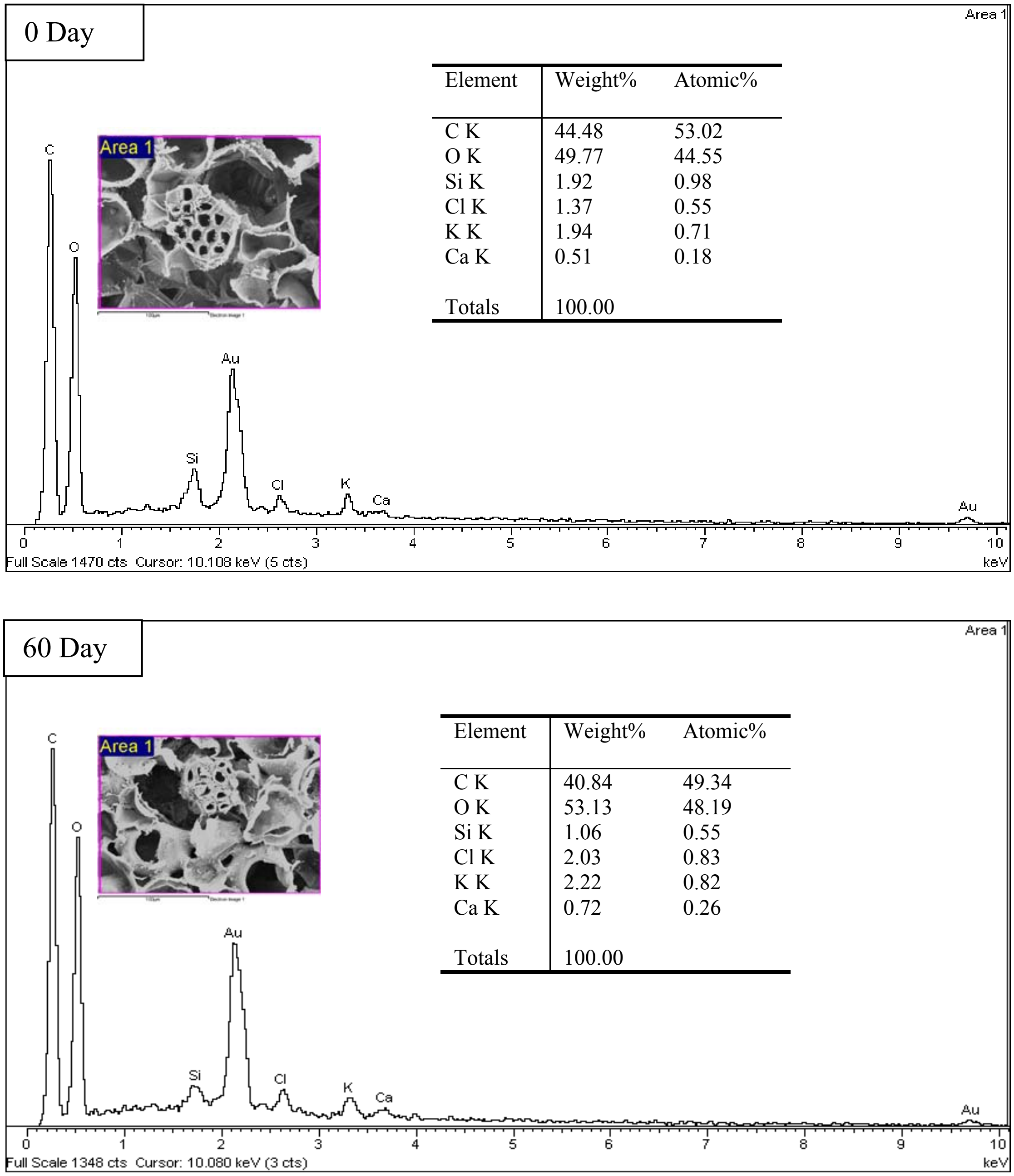
		Touch count (+)	Area (mm^2)	Percentage ratio (%) VB	P
Inner (a)	0 day	12	25.13	47.8	52.2
	45 day	11	18.83	54.9	45.1
	60 day	9	16.40	65.3	34.7
Middle (b)	0 day	16	25.13	50.0	50.0
	45 day	9	15.96	56.4	43.6
	60 day	8	16.00	72.2	27.8
Outer (c)	0 day	25	34.62	58.4	41.6
	45 day	27	31.56	63.7	36.3
	60 day	17	26.02	85.6	14.4

Table 1 displays the percentage of parenchyma and vascular bundle of oil palm trunk effect of storage time evaluated using an image analyzer calculated based on the results that were obtained from Fig. 6. The percentage of ratio showed that the vascular bundle and parenchyma of oil palm trunk for each part are similar with percentage ratio that was obtained by dried samples (Table 3).

The calculation from the image analyzer was carried out according to Eq. 1:

$$\text{Percentage of ratio} = \frac{\text{Touch count (+)}}{\text{Area (mm}^2\text{)}} \times 100 \qquad (1)$$

As a representative monocot species, oil palms do not have a vascular cambium and do not exhibit secondary growth by the production of concentric annual rings. They cannot increase in girth by adding lateral layers of cells, as in conifers and woody dicots. Instead, they have scattered vascular bundles composed of xylem and phloem tissue. Each bundle is surrounded by a ring of cells called a bundle sheath (Klein 1979).



0 Day

Element	Weight%	Atomic%
C K	44.48	53.02
O K	49.77	44.55
Si K	1.92	0.98
Cl K	1.37	0.55
K K	1.94	0.71
Ca K	0.51	0.18
Totals	100.00	

60 Day

Element	Weight%	Atomic%
C K	40.84	49.34
O K	53.13	48.19
Si K	1.06	0.55
Cl K	2.03	0.83
K K	2.22	0.82
Ca K	0.72	0.26
Totals	100.00	

Fig. 7. SEM-EDXA spectra of oil palm trunk with their elemental composition for 0 and 60 day

The inorganic constituents of the parenchyma and vascular of oil palm trunk were also studied by scanning electron microscopy equipped with energy dispersive X-ray analysis. Figure 7 shows the energy dispersive X-ray analysis (SEM-EDXA) spectra with the elemental composition of oil palm trunk. No specific difference was determined between the two samples. Both specimens had carbon and oxygen in a large weight percentage, while little of the potassium, chlorine, calcium, and silicon could have existed in oxide form.

Fourier Transform Infrared Spectroscopic (FTIR) Analysis

Fourier transforms infrared (FTIR) spectroscopy was used to detect the presence of the functional groups that exists in parenchyma and vascular bundle of oil palm trunk. FTIR spectra for parenchyma and vascular bundle are shown in Fig. 8. The spectra revealed the presence of different functional groups within the parenchyma and vascular bundle.

Figure 8 shows that the peaks of vascular bundle of oil palm trunk for 0 day appeared at 3333 and 1505 cm^{-1}, corresponding to O–H stretching and O–H bending frequencies, respectively, while the $–CH_2$ stretching frequency appeared at 2919 cm^{-1}. In the spectrum of the parenchyma of oil palm trunk for 0 day also illustrated in Fig. 8, the peaks appeared at 3354 and 1504 cm^{-1} corresponding to the O–H stretching and O–H bending frequencies, respectively, while the $–CH_2$ stretching frequency in this case appeared at 2927 cm^{-1}. In comparison, the peaks for the parenchyma shifted to higher frequencies as compared to the whole vascular bundle. In this case the peaks appeared in the vicinity of 3354 cm^{-1} for O–H stretches and 1504 cm^{-1} for O–H bending frequency. The CH_2 stretching frequency in this case appeared at slightly higher frequency and appeared at 2927 cm^{-1}. The blue shift in the O–H group frequencies of vascular bundle and parenchyma could be due to the different hydroxyl group content in the fibers in the form of cellulose, hemicelluloses, and lignin.

In the FTIR spectra, the other prominent absorbance peaks were in the range of 1740 to 1500 cm^{-1}. The peaks at 1733 and 1595 cm^{-1}, 1712 and 1608 cm^{-1}, respectively represent carbonyl stretching (C=O) for acetyl groups in hemicelluloses and for aldehydic group present in the lignin.

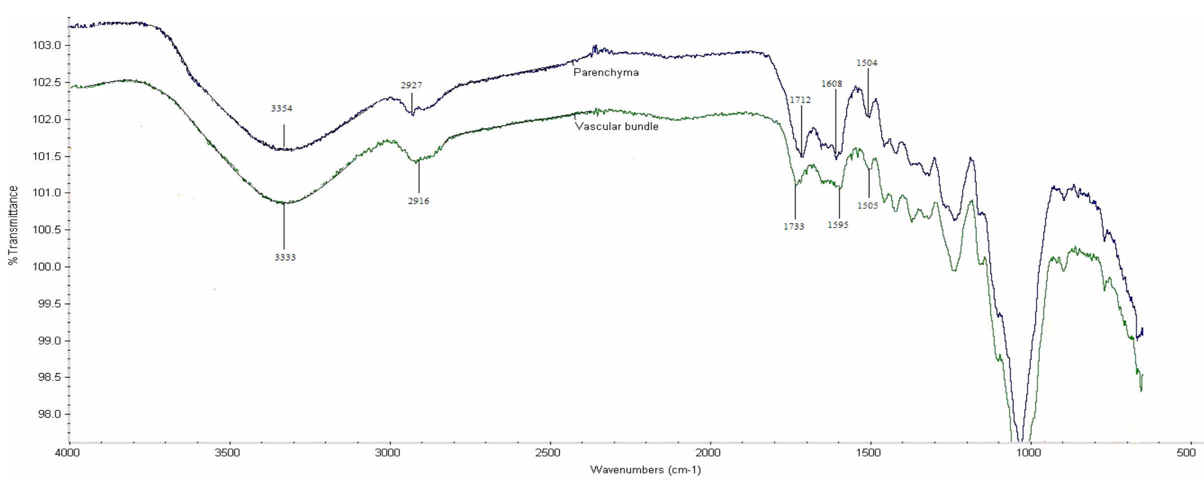


Fig. 8. FT -IR spectrum of parenchyma and vascular bundle in the frequency range of 400- 4000cm^{-1}

CONCLUSIONS

1. The presence of parenchyma and vascular bundle in each zone affect the moisture content in oil palm trunk. This study showed that inner part contains highest moisture content compared to middle and outer part.

2. Parenchyma has high capacity in absorbing water compared to vascular bundle that is less hygroscopic that could be due to its anatomical structure.

3. As a result of storage, the parenchyma content decreased in each part of the inner, middle and outer part of oil palm trunk, while the vascular bundle content increased.

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