Chapter

Chemical Composition of Parenchyma and Vascular Bundle from *Elaeis guineensis*

Sitti Fatimah Mhd. Ramle

Abstract

Elaeis guineensis is an alternative source of raw materials for renewable energy in Malaysia. Thus, to enhance the use of the abundant biomass generated by the oil palm industry in Malaysia, a study was conducted in view of exploring the chemical composition such as sugar potential of this industrial byproduct. In this context, oil palm trunks were separated into individual cell that are parenchyma and vascular bundle to investigate the fundamental research about oil palm trunk. The aim of this study was to examine the chemical composition of parenchyma and vascular bundle of oil palm trunk. The oil palm trunk was kept under shade at room temperature of 28–30°C for 0, 45, and 60 days. The chemical composition analysis was carried out according to TAPPI methods. Based on storage time and different part of oil palm trunk, the result has shown that the sugar content was higher in parenchyma compared to vascular bundle and increase at the storage time of 0, 45, and 60 days while amount of starch showed decrease at the same storage time. It shows that conversion or fermentation of starch to sugar occur in oil palm trunk during storage times of 0, 45, and 60 days, respectively.

Keywords: *Elaeis guineensis*, oil palm trunk, parenchyma, vascular bundle, storage

1. Introduction

Oil palm tree is one of the perennial oil crops that generate economic growth in Malaysia. It belongs in the species *Elaeis guineensis* under *Palmacea* family that comes from the tropical forests of West Africa. Palm oil production has almost doubled in the past decade. It is produced in 42 countries around the world at about 27 million hectares [1]. Oil palm cultivation has also become the first fruits of the world in terms of production for nearly 20 years.

Currently, Malaysia is the regional leader in biodiesel production with an output of 540 million liters per annum as of 2009 [2]. Meanwhile, Indonesia is second with the production of 400 million liters in 2010 [3]. During the process of replanting in Malaysia, large quantities of oil palm trunks (OPT) and oil palm fronds (OPF) waste are produced in oil palm plantations. The trunks are normally left in the field without any utilization thereafter. They are usually cut into pieces and burnt down to avoid insect and incidences [4].

Oil palm trunks have such special characteristics as high moisture content (1.5 to 2.5 times the weight of the dry matter), low cellulose and lignin content and high content of water soluble and NaOH soluble in comparison with rubberwood and bagasse. Physical properties of trunks showed heterogeneity and varied depending on both radial and vertical directions. Some difficulties in utilizing oil palm trunks also lie in extremely tough outer bark and high content of decay able parenchyma cells [5].

From the previous study [1, 6], found that the sugar content in the sap of felled palm trunks increased during storage after logging. This suggests that oil palm trunk can be a promising source of sugar as proper treatment after logging. Sap analysis can be an efficient raw material for bioethanol [6, 7]. In addition, oil palm trunk was considered as a useful material for pulp and paper properties which have been studied [5, 8, 9]. However, the physical, morphological properties and chemical compositions of individual cell of oil palm trunk such as parenchyma and vascular bundle have not been well studied [10].

The aim of this study therefore was to examine the chemical composition of parenchyma and vascular bundle of oil palm trunk that were separated based on storage time [11]. Fibers useful for materials occur in vascular bundle, while living cells containing sugars and starch useful for energy and livestock foods mainly exists in parenchyma. The outcome of this study forms the basis in realization of the full potential of the chemical compositions and it can guide us for particular applications and uses.

2. Overview of *Elaeis guineensis*

In Malaysia, the production of palm oil has tremendously increased since the 1970s. Government policy on crop diversity has led to an increase in hectares of oil palm trees as shown in **Figure 1**. In 1996, 2.6 million hectares were used for the cultivation of oil palm and this figure is staggering. In 2005 and 2010 the percentage changes in the areas of oil palm tree is about 20% for each of the next five years. The year 2011 has reached 5 million hectares but only three percent different from 2010. The rapid growth in oil palm cultivation has seen in five years of 1965–1970, 1970–1975, and also in 1975–1980. This is due to the crop diversification program [12].

Figure 1.
Oil palm plantation in Pahang, Malaysia.

2.1 Botanical description of *Elaeis guineensis*

The classification of the botanical description of oil palms has presented some problems; the rules of plant taxonomy demand that the name first correctly applied to a species must be used (though the generic name can be changed if research indicates that a species has been placed in the wrong genus). The African oil palm was named *Elaeis guineensis* by [13] and this name is not questioned. According to [14] the first valid name for the American species is Corozo oleifera, but [15] considered that the American and African species are so closely related that separation in different genera is not justified. This is supported by the production of viable seeds in controlled pollination trials between the two species [16]. The correct name for the American oil palm is therefore *Elaeis oleifera* (H.B.K.) Cortes. In the hybrids, *Elaeis oleifera* shows dominance over *Elaeis guineensis* for several characters, suggesting that *Elaeis oleifera* is more primitive and *Elaeis guineensis* represents a derived

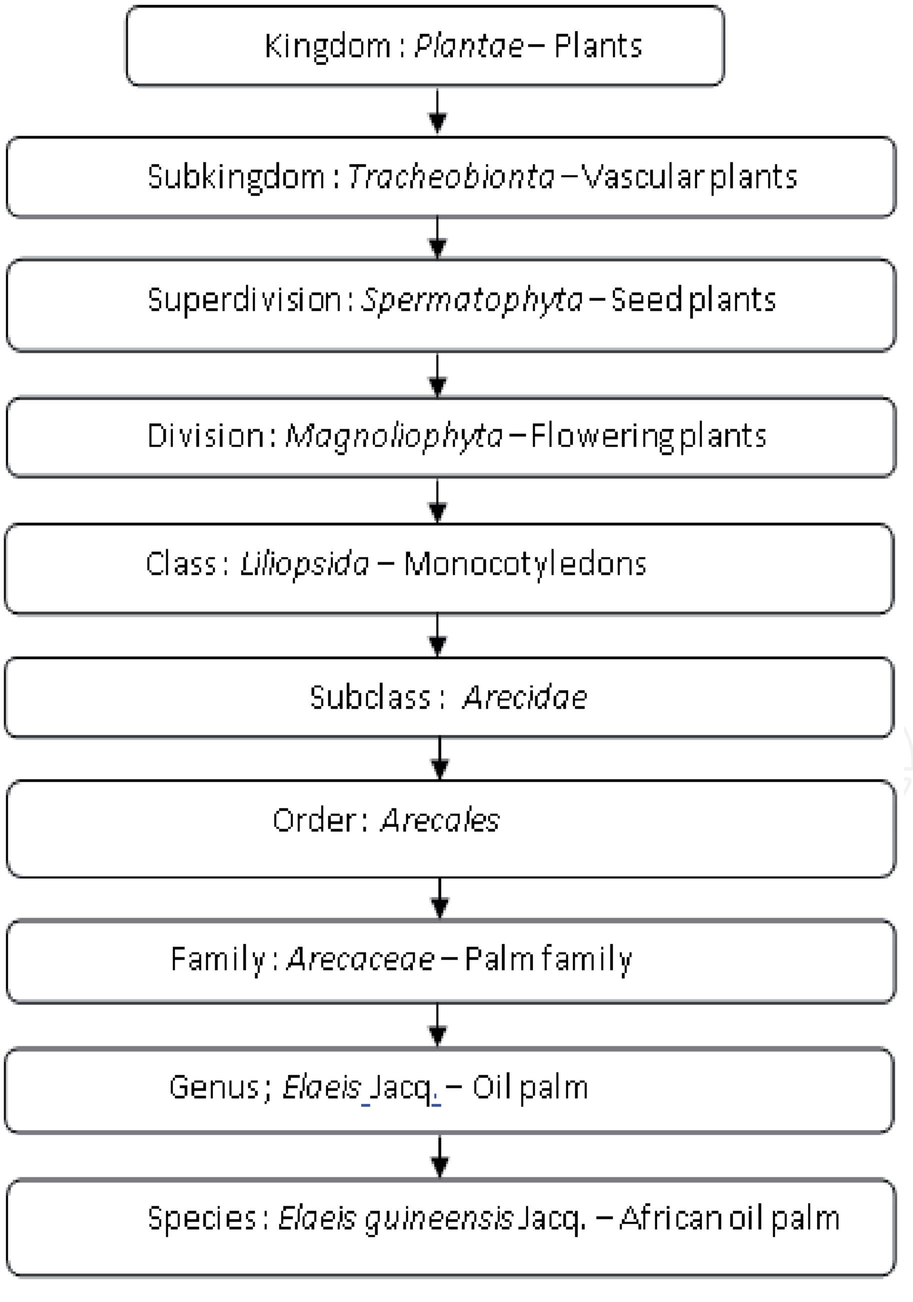

Figure 2.
Botanical description of oil palm.

species [17]. **Figure 2** present the oil palm profile according to the Plant, United State Department of Agriculture USDA [18].

2.2 Anatomy structure of *Elaeis guineensis*

Nonwood fibers are derived from selected tissues of various mono- or dicotyledonous plants [19] and are categorized botanically as grass, bast, leaf, or fruit fibers as can be seen in **Figure 3**. Nonwood fibers are classified as fibers such as sugar cane bagasse, wheat straw and corn stalks are byproducts. Other non-wood fibers are grouped as fiber plants which are plants with high cellulose content that are cultivated primarily for the sake of their fibers such as jute, kenaf, flax, cotton and ramie [20].

There are several types of nonwood produce useful byproducts, for example, oil of kenaf and flax seed. From nonwood fibers can also be used to make paper, although the quality varies as it depends on the fiber source [21]. The combination of wood and nonwood fiber can reduce the amount of chemicals needed for pulp. It also shortens the time the pulp, thus saving energy. High cellulose content of cotton linters (85–90%) compared to wood (35–49% cellulose), and low lignin content of hemp (3%) make valuable nonwood fibers for paper making [5].

In this study oil palm trunk was used and categorized in non-wood tree. Oil palm tree does not have cambium, secondary growth, growth ring, ray cell, sapwood, and heartwood or branches and knots. The anatomical structure of oil palm consists of parenchyma and vascular bundle, in contrast to hardwood and softwood which the cells consist of mostly fibers, trachieds, vessel parenchyma and

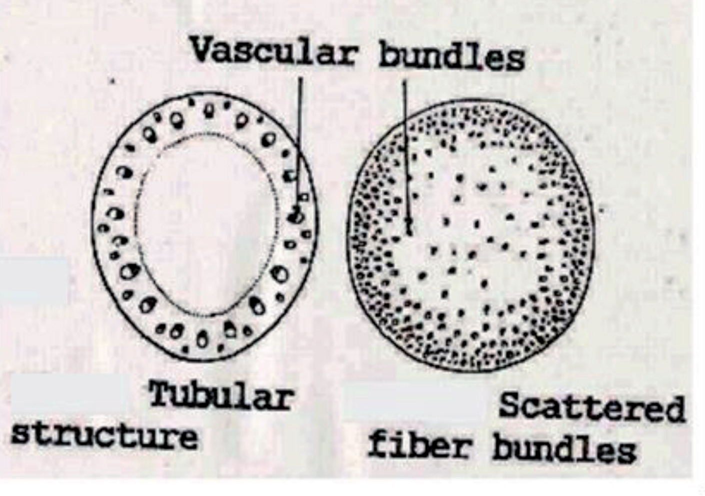

Figure 3.
Structure of non-wood.

Figure 4.
Separation of oil palm trunk into parenchyma and vascular bundle.

ray parenchyma cells. In this study focused on chemical compositions of separated sample of oil palm trunk which are parenchyma and vascular bundle as shown in **Figure 4**.

2.2.1 Parenchyma and vascular bundle from Elaeis guineensis

Parenchyma cells are the oldest type of eukaryotic cells that have been the first cell a grow. There is only a thin primary wall and lack of a secondary wall in the cell. Vascular bundle cells are called as a transportation tissue and grouped together with vascular tissue. Vascular tissue is made up from different types of plant cells and also called as a transportation system. The function of this tissue is to transfer the water, organic and inorganic molecules from synthesized or absorbed in the plant, to be used or stored by plant. The arrangement of the vascular tissue in a plant stem differs in dicotyledonous and monocotyledonous plants [22]. In this study we only focus on monocotyledon plants, which are oil palm trunk that was used in this study is one of the monocotyledon plant.

2.3 Utilization of biomass *Elaeis guineensis* to renewable energy

Biomass waste from palm oil is one of the solutions to the renewable energy because is believed to have availability and continuity. In the present situation, the oil palm biomass is one of the problems that have yet to be exploited. There are many considerations such as the economy, energy balance, environmental technology and the best solutions to meet the oil palm biomass utilization. All economic activity begins with physical materials and energy carriers (fuel and electricity). In the present era of transformation, we need a reliable source for sufficient sustainable energy requirements [23]. Otherwise have the materials, food, shelter technology will lead to no energy, no work and no economic activity [24].

The income and population growth have increased demand for energy. Energy is needed in almost all aspects of life, including agriculture, health care, drinking water, lighting, telecommunications and industrial activities. At this time, the demand for energy is fulfilled by fossil fuels (ie, coal, petroleum and natural gas). The world's current production rate of liquid fossil fuels (petroleum and natural gas) decrease in 2012 [25].

According to [26] due to high energy consumption and greenhouse gas emissions also cause a huge impact on global climate change. Based on existing scientific evaluation, observation records show that from the industrial era to the present day global average temperature has increased by between 0.3 and 0.6°C since the late 19th century, whereas sea levels have risen between 10 and 25 cm over the same period.

Biomass contributes about 12% on a worldwide scale. This causes the main energy supply increased to 40% and 50% of the country's most developed nations. In Malaysia, there are some examples of energy derived from biomass, including crop production resulting in starch, such as sorghum, or cane sugar as artichoke. Cellulose such as poplar, eucalyptus trees or other wood treelike form and sunflower oil is included in the energy-producing plants. There is a plentiful supply of palm oil waste and gives the reasons to choose the first biomass as a renewable and will be developed for large-scale applications, mainly in the palm oil industry [27]. In addition, palm oil waste can be considered as energy crops. This is because the palm oil industry has more than 40 years of experience in biomass power generation system operations and has working experience in use of palm oil waste to heat and power generation in the country [28].

3. Chemical composition of *Elaeis guineensis*

Chemical composition varies from species to species and within different parts of the same wood species. Chemical composition also varies within woods from different geographic locations, ages, climates and soil conditions [29].

Based on previous study, oil palm is a lignocelluloses material that contains a high level of carbohydrates [30]. These carbohydrates are mainly in the form of sugar containing cellulose, starch, hemicelluloses, and lignin [30] also found that the chemical compositions of oil palm biomass consists of high holocellulose, lignin, starch, and sugar contents that have been found to aid in the production of binderless panels.

According to [30] starch content is high in parenchyma cells. It is due to the starch of the oil palm trunk is stored inside the parenchyma cells of the coarse vascular bundles, which contain a high percentage of lignin. However, the data about the individual cell of parenchyma and vascular bundle are still limited and need future investigating. In this study, the chemical compositions are focused on starch and sugar of oil palm trunk during storage time.

3.1 Sugar content of parenchyma and vascular bundle at different part of oil palm trunk by HLPC

The **Figure 5** shows the results of the sugar content for separated samples (parenchyma and vascular bundle) and a non-separated sample of oil palm trunk at different part during storage time. From the figure showed that the parenchyma gave the most concentration of sugar compared to the vascular bundle. Non-separated sample at the bottom part of oil palm trunk showed a slightly highest of sugar content compared to the non-separated samples on the top part. Different parts such as inner, middle and outer part showed that the parenchyma in the middle contains the highest sugar content compared to others.

Based on this study, the highest sugar content was found in the parenchyma and bottom part of the oil palm trunk for the non-separated sample at the different part

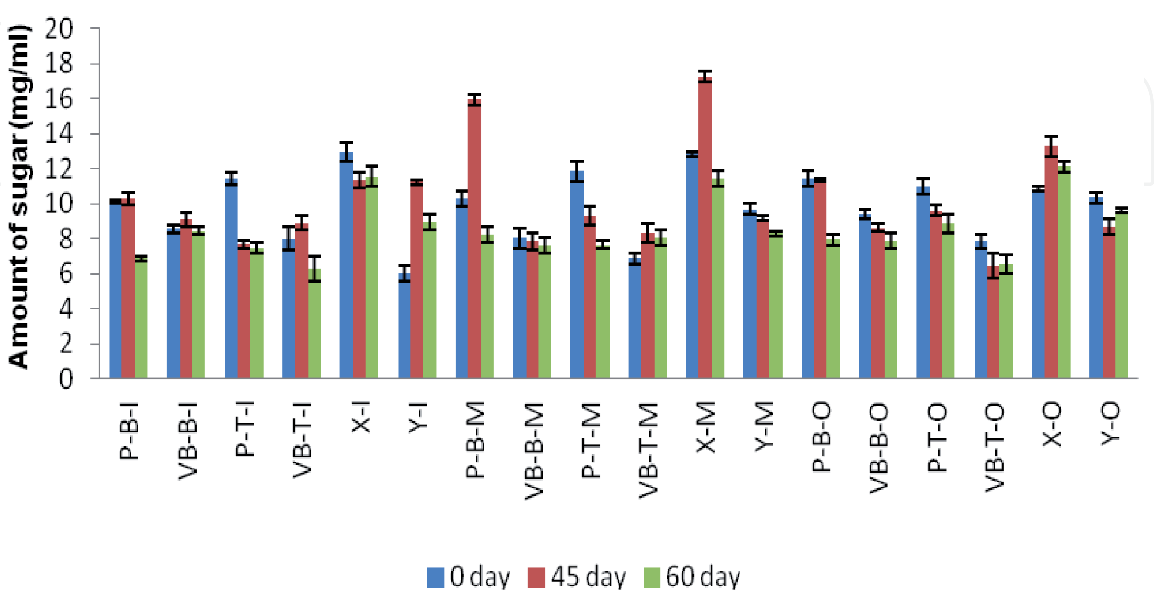

Figure 5.
Amount of sugar content of bottom and top part oil palm trunk during storage time. P-B, parenchyma-bottom; VB-B, vascular bundle-bottom; P–T, parenchyma-top; VB-T, vascular bundle-top; X, bottom non-separated; Y, top non-separated; I, inner; M, middle; O, outer.

during storage time which contains more parenchyma compared to the top part of the non-separated samples. The difference between these is probably due to the function of parenchyma as a storage organ and contain abundant amount of sap and nutrients which is rich in oligosacchides compare to vascular bundle that function as a mechanical support of the oil palm trunk [31].

The studies of 0, 45 and 60 day had been chosen to observe the potential sugar increase to optimum yield of storage time that was obtained. This storage time was chosen based on previous studies which 0, 45 and 60 days. From the **Figure 5** also showed the sugar content with the average at 0 days was 8–10 mg/ml and slightly increases at 45 days with the sugar content average at 10–17 mg/ml. At the 60 day, the sugar content decrease to 8 mg/ml and this pattern is similar to the separated sample and non-separated sample of oil palm trunk. The figure also showed that the bottom part of the middle part of the oil palm trunk of individual parenchyma and non-separated has the highest sugar content at 45 days compared to others. Amount of sugar in the individual parenchyma at the middle part is 16.0 mg/ml at the bottom part whereas non-separated sample of the bottom part of oil palm trunk at the middle part is 17.3 mg/ml. The lowest sugar content at 45 days are shown in the individual vascular bundle at the top part of the outer part of the oil palm trunk with the amount of sugar content is 6.5 mg/ml whereas for the non-separated sample show that the top part of the outer part of the oil palm trunk contain 8.73 mg/ml of sugar content.

Based on the results it was observed that the pattern results of sugar content for all samples increased as the duration of storage increased. Based on the findings of this study, the sugar content at day 0 initially increased and decreased rapidly around day 45 to 60. This changing pattern may happened because of the starch in the oil palm trunk probably was being converted to glucose and other fermentable sugar by enzyme activities. These activities probably involved degrading enzyme and sucrose metabolism enzymes [7]. The error bars in the **Figure 5** represent the differences were statistically significant for parenchyma and vascular bundle of oil palm trunk based on storage time.

3.2 Starch analysis of parenchyma and vascular bundle of oil palm trunk

Figure 6 showed the percentage of starch content for separated sample (parenchyma and vascular bundle) and non-separated (mixture parenchyma and vascular bundle) sample from inner to outer of oil palm disks. The duration of the storage time was determined between 0, 45 and 60 days were used similar as the determination of sugar content of oil palm trunk.

Based on this study, the middle part of the oil palm trunk had the highest starch content compared to the outer and the inner part. The amount of the starch content in the middle part showed with a range 3–5%, whereas in the inner part in a range 2–4% and in the outer part around 3–4% in the 0 days. Parenchyma at the bottom part in the middle part showed the highest starch content compared to others which is 4.54% at 0 days whereas parenchyma at the top part in the inner part showed the highest starch content which is 3.5% at 45 days. Referring to previous studies on the starch content for a 0 day, as indicated by Tomimura (1992), the starch content for separated sample of vascular bundle and parenchyma was 2.4% while in parenchyma was 55.5% respectively.

The pattern results of starch content for all samples were reduced as the duration of storage increased. Based on the findings of this study, the starch content at day 0 initially to increase and decrease rapidly around day 45 to 60 and became almost negligible after 60 days. This changing pattern may happened because of the starch probably been converted to glucose and other fermentable sugar by enzyme

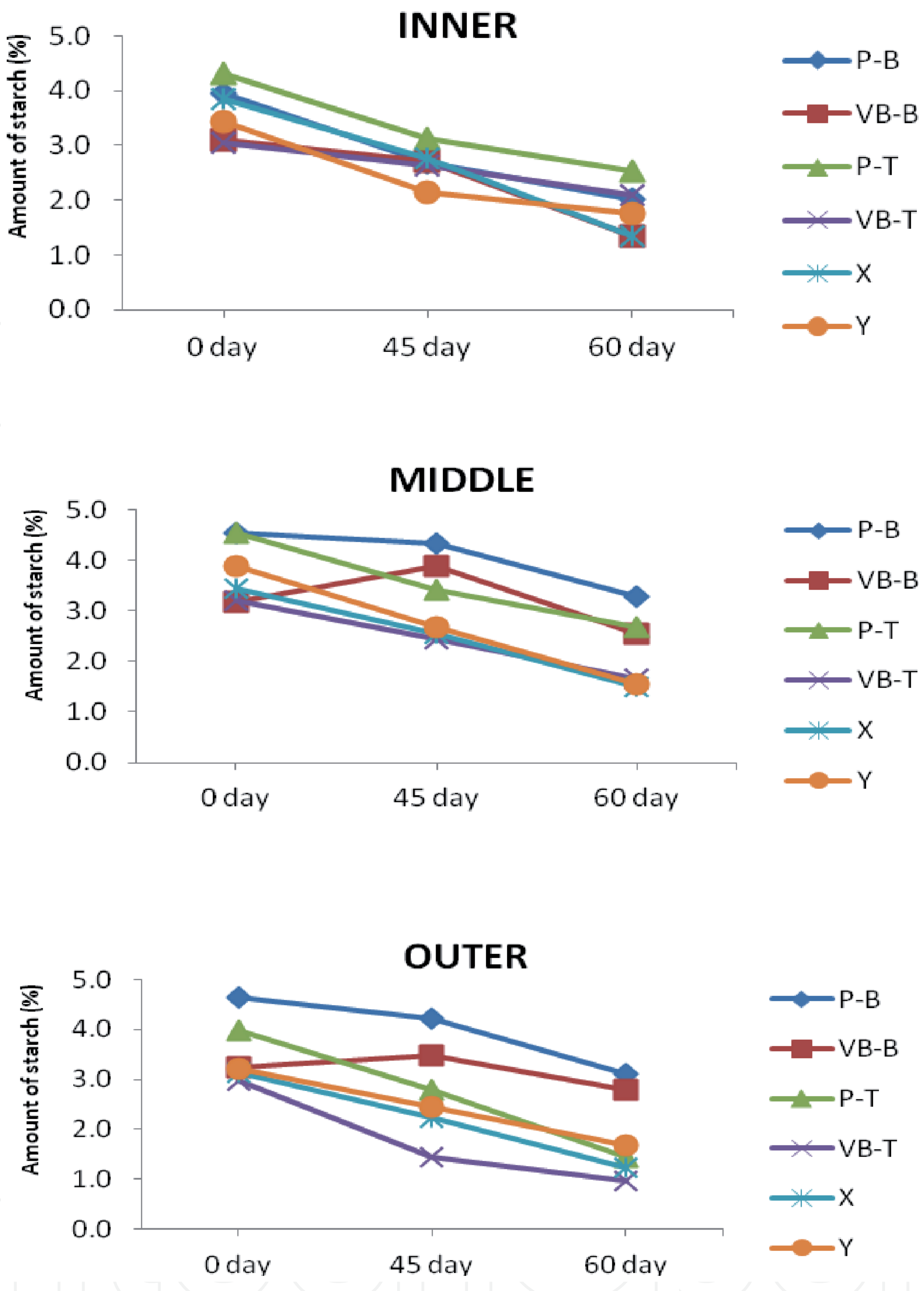

Figure 6.
Amount of starch content at different part of the oil palm trunk during storage time. P-B, parenchyma-bottom; VB-B, vascular bundle-bottom; P–T, parenchyma-top; VB-T, vascular bundle-top; X, bottom non-separated; Y, top non-separated.

activities. These activities probably involve degrading enzyme and sucrose metabolism enzymes [10]. In this study we only focused on 0, 45 and 60 day because it is the optimal day according to the previous study.

This research showed that the higher starch content had been found in the parenchyma comparatively to vascular bundle. Abundant amount of parenchymatous tissue which is rich in starch content accumulates in these parts [32]. According to [32] study, the carbohydrate content in oil palm trunks reported that peripheral cortex contains high starch level. This study showed that the middle part contained the highest starch content which is being different from the previous study. This may be due to the different types of cultivar has been used.

According [32] found that high level of starch content was located dominantly in the top part of oil palm trunk. This phenomenon relates to an older cells distribute in basal part of the oil palm trunk compared to top part that contain young cells. As young cells, it needs a lot of carbohydrates which is consisting of the abundant amount of starch content, reserved for the growing process [33]. This statement was supported by [31] in his report that starch stored in the upper part of the tree is purposely used for flowering process.

4. Conclusions

The chemical compositions that were determined in this study consisted of starch, and sugar of parenchyma and vascular bundle of oil palm trunk. Regarding in this study, parenchyma showed higher extractive content compared to the vascular bundle during the storage time while, parenchyma on the top parts showed slightly higher instructive compared to the parenchyma bottom. Vascular bundle on the bottom and top part of the trunk have the highest percentage of holocellulose which are range 80–85% compared to the parenchyma on the bottom and top part that around 65–75%.

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Conflict of interest

I declare that this chapter entitled "Chemical composition of parenchyma and vascular bundle from *Elaeis guineensis*" is the results of my own research except as cited in the references.

Notes/thanks/other declarations

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