

# The effect of power intensity properties of microwave modified oil palm trunk lumber

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**Abstract.** In the decade, oil palm (*Elaeis guineensis*) in Malaysia is one of the conventional sources that will be rising, and the rate of biomass will considerably increase in yet to come. Presently, oil palm biomass is going through research and development and appears to be the most sustainable alternative. Investigations on oil palm biomass have been conducted to support in draw out waste of oil palm and in the meantime can help economic yield to the country. This study was expected to estimate the effect of power intensity properties of microwave modified oil palm trunk lumber. Microwave treatment of oil palm trunk samples was set of connections by using a microwave operating at 2.45 GHz with the liberated process input power intensity (600-1000W) were studied under the given condition. Impact and compression of the samples were tested. The analysis of properties of the fresh material and dry samples was employed by scanning electron microscopy. Oven drying technique also was involved as a comparison of the conventional drying process in this research. Based on the outcomes of this study, both drying methods improved the characteristics of the specimens.

## 1. Introduction

In timber-based manufacturing, the unavailability of wood as a raw material has recently become a significant apprehension. Many plants that produce timber-based products, especially plywood and lumber, already shut down. Wood-based industries are now fronting a difficult with the supply of raw materials, not only from natural forests but also rubber plantations. Year after year, it is expected that at least 20 million tonnes of solid wood are used in timber-based manufacturing. Currently, supplies of wood are becoming restricted, and oil palm trunk could be potential substitutes source to replace wood [1]. Oil palm trunk (OPT) is especially promising, as it can be used as a value-added product as well as in future wood-based industries [2]. However, fresh oil palm trunk contains high humidity that could reach as high as 500% based oven-dry weight, and when degraded it could pollute the surrounding environment [3]. Before oil palm trunks could be used as raw materials for manufacture products, the oil palm trunk was usually condensed to smaller sizes in chips form and dried to moisture content around 7-10% [4]. Due to high moisture content, the oil palm trunk is very liable to fungal attack and will worsen quickly. Thus, desiccating the oil palm trunk to adequate moisture content should be done as soon as possible.



Oil palm is monocotyledonous species that does not have cambium, growth ring and ring cells in contrast to tropical woody plants. However, it consists of mostly parenchymatous ground materials and vascular bundles [5]. Vascular bundle and parenchyma tissues in oil palms are anatomically different from wood species. Oil palm trunks have some unique characteristics, including being accomplished 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 [6]. However, oil palm trunk has very low natural durability due to the existence of sugar and starch in oil palm parenchyma tissues. Due to very high sugar and starch contents, oil palm trunk is very susceptible to the attack by genetic agents such as termites and fungi. Ramle et al. [6] determined that parenchyma cells have high capacity in absorbing water of water absorption as compared to the vascular bundle that could be connected to their anatomical structure [7].

The properties and feature of the product produced are also profoundly influenced by the moisture content. The primary objective of drying is to diminish the moisture to a certain level at which on further drying, no remarkable change in volume and weight of the material will take place. Also, the low moisture content will allow the materials to be kept at a longer time without any fungal attack [3]. Drying of biomass like oil palm trunk is a complex process of heat and mass transfer. The mass loss during drying mostly following the falling rate curves. The water loss from the bulk of the fibrous material is controlled by the capillary action and internal diffusion of water molecules. This loss of water caused the shrinkage of the biomass [8]. Kiln drying process, oven drying process, and air drying process are the conventional drying methods used in industry. These dryers cause drying defects such as warping, raise grain, collapse with low recovery and require the considerable amount of energy and long drying times to obtain high-quality woods, even when using laboratory [1, 9]. Microwave technique is believed more efficient, fast, and also can reduce the drying times and at the same time can increase the production. Thus, it is considered that microwave drying process can reduce the moisture content with fewer defects to the trunk itself [10].

Strong prominence has currently been done to invent and to lessen the cost of drying [11]. Microwave processing technologies are developing rapidly in all industries [12]. Microwave drying would be new-fangled in the wood industry, but it has been used in our daily life including food processing and telecommunication. The application of microwave technology has been proved to improve drying time and could increase the drying rate compared with the conventional drying methods [13, 14]. Researchers indicate that microwave drying with proper selection of power input, the weight of drying material and drying time could increase the drying rate. As a result, it could save up to 50% of energy and significantly decrease volatile organic compound emissions when compared with the conventional drying methods. It can be concluded that the microwave energy consumption is relatively higher than oven drying based on watt/h. Considering much lower time will make the total energy consumed to be significantly lower than conventional methods. Thus, this study aimed to optimize the drying conditions using a microwave to enhance a complete drying, avoid burning, shrinkage, and swelling and increase the permeability of oil palm trunk so it could be improved to a value-added material [13].

## **2. Material and methods**

Oil palm trunk samples were harvested from a local plantation in Northern Malaysia. The trunk were sawn into round disks 10 cm in diameter before they was reduced to approximate dimensions of 16 cm x 6 cm x 4 cm with the utility of laboratory-type band saw. Then, the oil palm samples were cut into specific size for each method and testing. The moisture content and weight of oil palm trunk sample were taken during experimental work.

**Table 1.** Amount of sample and techniques used in experimental work.

Type of method	Amount of sample
Microwave drying	3 : (600 W, 800 W, 1000 W) for 10 min
Oven drying	1 : (105 °C, 24 hours)
Fresh oil palm trunk	1 : Fresh from freezer to avoid fungal attack

### 2.1. Oven drying process

The sample with preferred weight and initial moisture of 50% was oven dried (Model Memmert Universal Oven UF55) at 105°C to compare the effect of drying with microwave heat source. The drying was varied for 24 hours as shown in table 1.

### 2.2. Microwave radiation process

There were three different microwave treatment combinations of power intensity with one fresh sample as a control. All of the oil palm trunk blocks were standardize to the size of 165 mm x 65 mm x 40 mm as that is the most excellent size for the block to be placed inside the microwave space. The three combinations of microwave power and exposure time were stated in table 1.

### 2.3. Evaluation of mechanical properties of the samples

The samples were cut from the trunk to its specific size for impact testing and compressive strength testing. Mechanical features in the form of impact testing of the samples were determined for each condition of power intensity of microwave drying as well as oven and fresh sample. The impact strength of the oil palm samples has been identified by an Izod impact tester instrument. Minimum of 5 samples with dimensions of 60 mm x 13 mm x 5 mm have been used for the mechanical tests, and the value has been presented in this paper. Ten samples with measurement 6 cm x 2cm x 2cm from each panel were used for compression test using 5KN Celtron compression testing. The moisture content and weight of each sample were stately before they were experiencing microwave and oven drying process.

### 2.4. Scanning Electron Microscopy (SEM) analysis

The cross-section of oil palm trunk samples with dimensions of 1 cm x 1 cm was taken from each sample for testing. The samples were observed for microscopic analysis using a scanning electron microscope Quanta 450.

## 3. Result and discussion

### 3.1. Moisture content measurement

The moisture content of oil palm trunk samples before and after drying process was summarized in table 2. This indicates that each of the microwave treatment combinations and oven drying process can significantly reduce the moisture content.

**Table 2.** The moisture content measurement of drying process treatment.

Type of sample	Moisture content after (%)
Oven drying process	0.61
Microwave drying (600 W)	31.18
Microwave drying (800 W)	11.78
Microwave drying (1000 W)	6.88

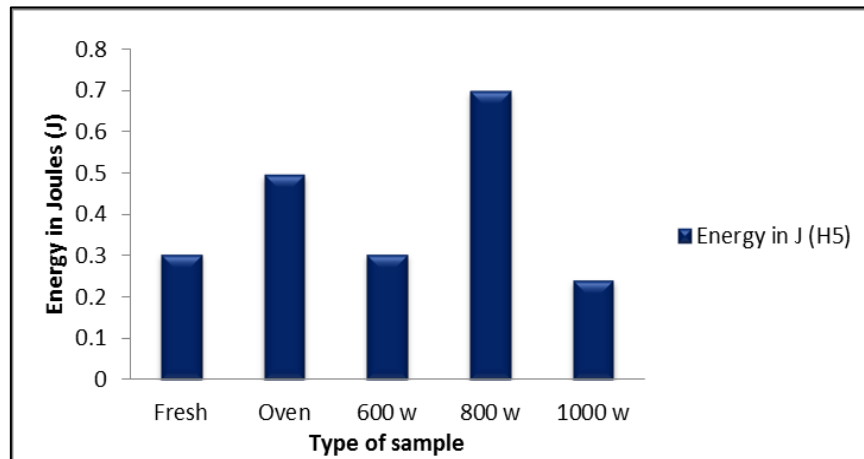
From table 2, oven drying process has the highest reduction of the moisture content of oil palm trunk sample. From 50% to 0.6% of moisture content, oven drying process could be the right method for drying industry. Nevertheless, microwave drying reveals more effectiveness and improvement of oil palm trunk sample. In this study, microwave drying in 600-watt shows the highest amount of reduction in moisture content percentage of moisture reduction of approximately 31.18% while microwave treatment of 800-watt power produced the better rate of moisture reduction compare to 600-watt. However, microwave drying at 1000-watt power for 10 minutes with a percentage of moisture reduction approximately 6.88% probably is the better combination of power intensity and exposure time to oil palm trunk sample in drying trade. This is because when microwave treatment of 1000-watt took place, the sample is dried out consistently and shrinkage did not occur. It was observed that there is no shrinkage occurs in the samples. It is also noted that to obtain nearly 30-40% of moisture content in dried oil palm trunk samples, only 10 min microwave drying time is required. Hence, microwave drying was found to be very useful for the removal of moisture in short time.

During microwave treatment, water is drawn from oil palm trunk cells permitting the material to dry. The microwave heating process took about 10 minutes to complete. This is much quicker than other ways and means which may take several weeks, such as air drying, oven drying, and kiln drying. The dissimilarity of moisture content inside the main part of the samples results in the variety of microwave absorbed energy. Microwave drying consists typically of three different periods: warm up, water evaporation and heating up. Water vaporized faster during drying process when the moisture content is very high. During the heating-up period, some of the microwave energy was used to heat up the strands. The temperature of strands would sometimes be so high that the strand surfaces would burn. Accordingly, many commercial wood drying operations impose an extended period of air drying to reduce the occurrence of drying defects before main drying stage [15, 16]. During microwave aeration, the warm-up period was shorter, and the boiling point was reached faster, which might increase the drying speed. In microwave drying, the interactions of water molecules inside wood generate heat. When the drying temperature is close to the boiling point, it will cause burning of the sample due to surface dehydration. However, the microwave-dried sample was utterly acceptable in behavior and appearance of the sample [17].

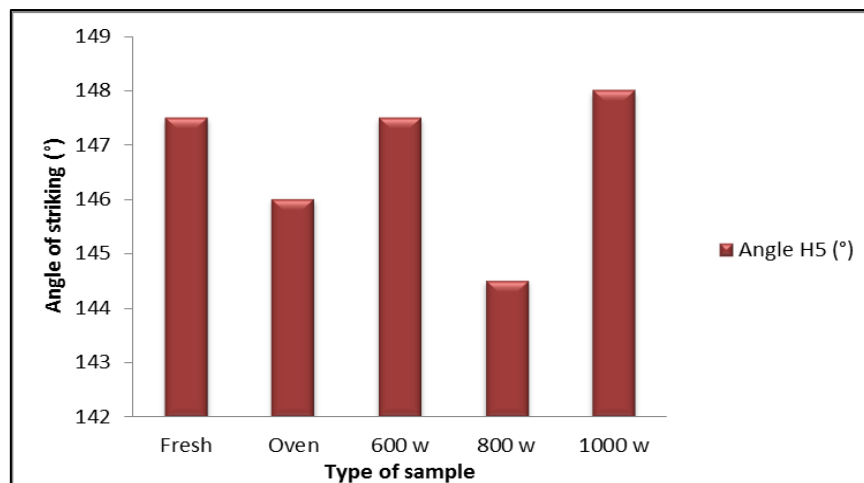
### 3.2. Impact strength

Figure 1 shows the impact strength of five oil palm samples in term of the H5 farming hammer. There

were some types of hammer in which H1 to H5. The differences of all farming hammer due to their weight and momentum of striker strikes sliding, hitting the test material in the middle, at the bottom of its swing.



**Figure 1.** Impact strength of 5 samples of oil palm in Joules (J).



**Figure 2.** Angle of striking of oil palm samples (°).

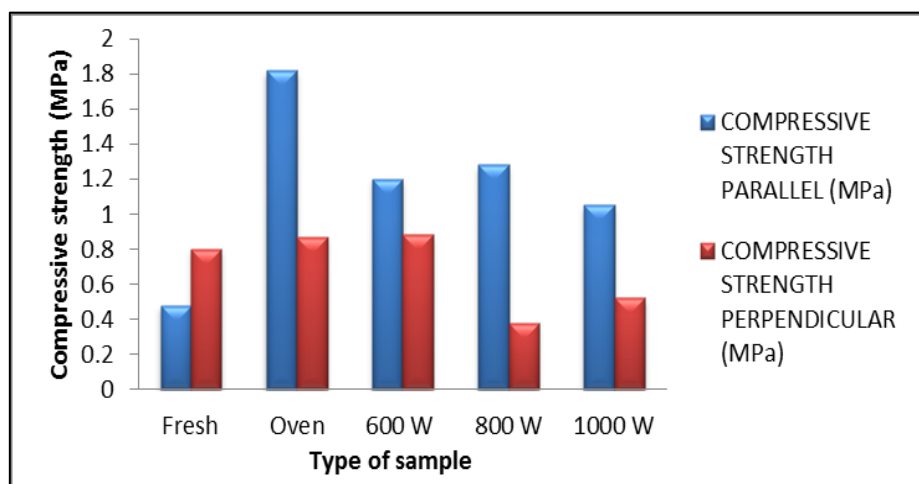
From the graph, it demonstrated the amount of energy engaged by microwave 800W material during breakage was the highest among all the samples. The absorbed energy was a measure of a given material's toughness and the more upper resulting numbers, the more robust the material. Among of three samples of microwave radiation process, the sample of 1000 W was the lowest compared to 600 W and 800 W. This is because higher input power intensity probably shrunk the cell structure of oil palm trunk and also reduced the strong point of the sample. From previous research, it was predicted that 1000 W would create the highest moisture content in the samples as more top power intensity input results in the temperature increase at even higher moisture content. However, in this study, it was verified that exposure time also influenced the moisture reduction [1]. For oven drying process and fresh sample, it showed a massive difference. The energy of the fresh sample was the lowest energy because the fresh sample had more moisture content and influenced the toughness of the

sample. Meanwhile, for oven drying sample, the moisture content was utterly the lowest because the sample was dried entirely at 105°C for 24 hours. To compare between an oven drying and fresh sample, ultimately the energy of oven sample more higher than the fresh sample. However, the amount of energy of 800 W microwave drying was more significant than oven sample. So, the conclusion showed that the microwave drying significantly more efficient and save power consumption as well as the drying process do not take more time.

Figure 2 display the angle of striking of Izod impact test in which the only one to determine the imperfections in material likely to fracture by "shock." Once the analysis was complete, the hammer was automatically seized and reverted to its starting point. This allows the starting angle to be changed according to the test, which enables optimum test parameters, such as impact speed and striking angle, to measure. From Figure 2, 800 W microwave drying technique and oven drying have less angle striking. The angle of hitting of the hammer for Izod test = 90°. The test specimen absorbed energy when it breaks. So the hammer does not rose high during the test if the material absorbed more energy. From the graph of angle striking of five types of samples, it can eventually say, the higher the energy consumed by an element when fracture, the lower the angle striking of the test specimen. However, there was some imperfection data due to the sample has high angle hitting but less energy absorbed during its break. A material's toughness was a dynamic in its capability to absorb energy during distortion. The impact rate of an element can also change with temperature. Generally, at lower temperatures, the impact energy of the material was decreased. The size of the sample may also affect the value of the Izod impact test because it may consent a diverse number of failures in the material, which can act as stress risers and lower the impact energy.

### 3.3. Compressive strength

Figure 3 shows the compressive strength of microwave drying, oven drying and the fresh sample of oil palm trunk. In the place that can be seen from the graph, there was a comparison of the compressive strength of parallel to grain and perpendicular to the grain oil palm trunk sample.



**Figure 3.** The compressive strength of parallel and perpendicular to the oil palm grain.

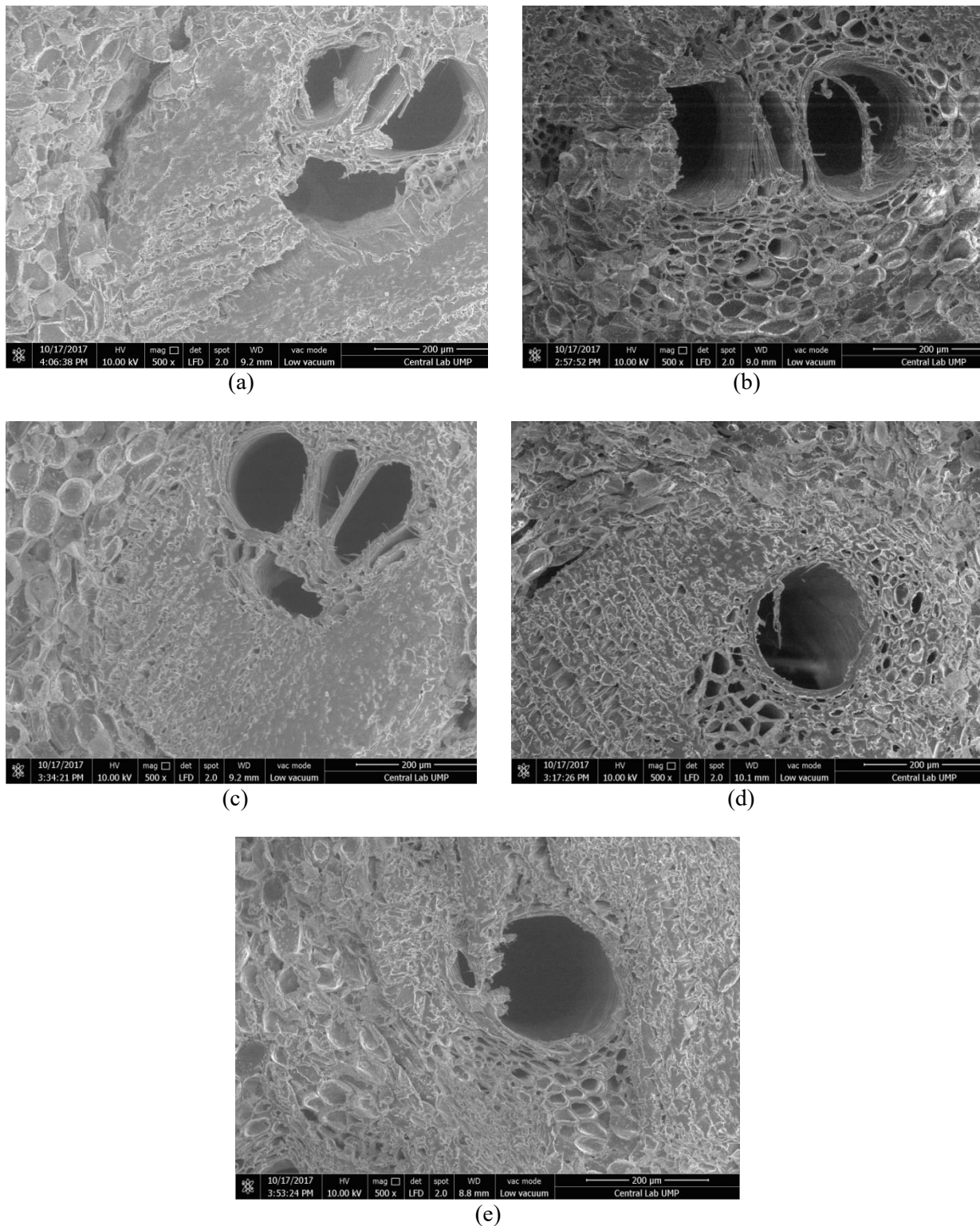
The amount of compression strength which undergo treatment variants 600 W 800 W and 1000 W parallel and perpendicular of grain were 1.2 MPa, 1.28 MPa, 1.05 MPa and 0.88 MPa, 0.38 MPa, 0.52 MPa respectively. Oven drying sample has an amount of 1.82 MPa for parallel grain and 0.87 MPa for perpendicular grain. Furthermore, the fresh sample displayed 0.48 MPa for parallel grain and 0.80 MPa for perpendicular grain. The compressive strength of parallel grain at every drying treatment was completely different in comparison to the perpendicular of grain included the fresh sample. Based on the graph, the parallel grain of drying samples has higher strength compared to the perpendicular grain. The perpendicular to grain compressive strong point of timber is known to be much lower than the strength parallel to the grain. Many timber structures, however, rely on this property especially in bearings that frequently occur in building practice. The linear elastic-plastic behavior of structural timber loaded perpendicular to grain has been a problematic issue for decades which is reflected in the differences between the prediction models in structural design codes over the world [18]. Other than that, the compressive strength of parallel grain oven drying shows the most upper power. This is because the oven was drying and completely removed the moisture content sample to 1%. However, the oven drying process takes a lot of time and power consuming throughout the process.

For the compressive strength of parallel grain, there was a less significant difference between each treatment of microwave treatments for 600 W, 800 W and 1000 W. For 800 W of microwave technique clearly has excellent strength compared to 600 W and 1000 W. This could be the concerns of the higher drying rate in microwave treatment compared to the conventional method. According to [14], microwave drying process usually undergoes three distinct stages; a warm-up step where the temperatures are rising, evaporation stage where the temperature is constant or plateau while the moisture evaporates, and heating-up stage which the water is done evaporate but increase in the temperature of the specimen body. The same stages were also occurrence in convective drying. However, in convective drying the warm-up stage and to achieve the plateau temperature (boiling point of water) take a longer time. Microwave treatment enables shortening both of these stages resulting in a better drying rate. With better drying rate, the material becomes less hygroscopic as stated by [19]. Lignocellulosic material that treated with high temperature was less absorption and desorption rate as compared to untreated. Less hygroscopic materials contain less moisture bound in their fibers which improves the mechanical properties of the samples [20].

#### *3.4. Scanning electron microscopy (SEM)*

The effects of drying techniques of oil palm trunk samples were perceived by SEM analysis. Figure 4 displays the SEM analysis of (a) fresh oil palm trunk, (b) oven drying and (c) (d) (e) microwave radiation process.





**Figure 4.** SEM micrographs of oil palm trunk vascular bundle (x500) (a) fresh sample (b) oven drying process (c) 600 W microwave drying process (d) 800 W microwave drying process (e) 1000 W microwave drying process.



The logs are composed of vascular bundle and parenchymatous tissue which act as transporting and food storing organs, respectively [21]. From the figure, the vascular bundle of fresh sample smaller than oven drying sample. Regarding for microwave drying technique, it showed the vascular bunch of 1000 W and 800 W bigger than the vascular bundle of 600 W. The shape was formed probably due to the result of temperature and power intensity of drying process respectively. Hence, the higher the temperature and heat transfer, the bigger the vascular bundle of oil palm trunk sample. The vascular bundle was found more in the outer zone of the trunks compared to the central zones, the fiber becomes shorter and having a smaller diameter and thicker cell walls..

#### 4. Conclusion

The properties of oil palm trunk wood were improved with the treatment of microwave radiation process. However, oven drying sample also showed improvement after treatment. But microwave drying technique was more efficient and can reduce the cost of drying. The sample of microwave treatment of 800 watts power intensity with 10 minutes duration showed the highest strength value in the series of treatment which consists of different wattage power. Hence, the sample could be used as a reference to enhance the strength properties of oil palm trunk wood.

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