Drying Effect by Combination of Chemical and Microwave Treatment of Oil Palm Trunk

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Abstract. Oil palm plantation is one multibillion-dollar commodity crops in Malaysia. All part of palm tree is reusable which no parts will turn into waste. Oil palm trunk has cellulosic structure that is categorised as woody materials. Current issue is the drying process of the oil palm trunk is too long and it can be reduced by chemically and microwave treatment. The treatment densified and compacted the oil palm trunk into other woody elements. The experimental study investigated the chemical treatment by varying dipping time in methanol between 5 to 20 minutes and microwave power input ranges between 40% to 100%. The combination treatment of 80% microwave power and 15 minutes dipping in methanol give the highest moisture reduction. The morphological aspect of palm trunk was investigate using LEO Supra 50 Vp field emission scanning electron microscope (FESEM) with ultra-high resolution.

1. Introduction
Although oil palm trunk (OPT) does not produce ‘wood’ in the usual sense of the wood, but their trunks are physically hard. Besides, OPTs are among oil palm residues that offer the best properties as compared to those of the wood. Therefore, woody materials from OPT are also referred as oil palm wood. Generally, OPT is comprised of cellulosic fibers cemented by lignin that resembles timber wood [1]. Based on the feature of its structure, OPT is closer to hardwood.

The chemical properties of OPT are summarised based on the height portions which the ash, alkali and alcohol content is increase linearly and on the other hand, the lignin and alpha-cellulose content decrease linearly. A study was done on OPT nanofibers confirmed that cellulose content was increased after alkali and acid treatment and also led to partial removal of hemicelluloses and lignin from the structure of the fibers [2].

The main concern of OPT is the moisture content within the trunk. Drying the OPT consume time and energy and the effective method of drying is the major concern as to reduce time and energy as well as to preserve it properties. It is also known that natural fibre is porous where the particle size and porosity determine the fluid flow which the heat transfer mechanism in each layer of porous materials is strongly influenced the drying process [3]. Thermally-compressed OPT samples having better mechanical properties but induced thickness swelling due to cracks of cell walls of parenchyma cells after compression at high temperature [4].

Drying using microwave power method is found effective in the previous studies. Microwave technology provides significant material and energy savings, besides it has been investigated to treat refractory wood species with preservatives, rapid drying of hardwoods, relief of growth and drying stresses in timber, manufacture of the new wood materials [5]. The overall drying kinetics was improved by varying the drying parameters such as time of radiation process, air temperature, sample
thickness, and microwave power level [6]. Microwave wood modification at different GHz increase in wood permeability and it indicate that this technology could be applied to any wood species [7]. Besides, microwave power assisted wood preservative treatments by lowering swelling and water absorption values for selected hardwoods and softwood species which microwave induce further reaction or bonding to hydroxyl group (–C-OH) of cell wall constituents to create further water repellent (hydrophobic) surfaces [8].

Characteristics of microwave drying at different power inputs on wood strands with different initial moisture contents and geometries showed that the drying rate was increased, save up to 50% of energy consumption, and decrease volatile organic compound (VOC) 20 emissions when compared with the conventional drying method [9]. This is because in the conventional heating processes, the heating process take place at the materials surface first then moves inwards. In the microwave process, the materials is heated entire volume at about the same time [10].

In this study a combination of chemical treatment using methanol and microwave power were investigated on the moisture content and morphology of the OPT.

2. Methodology

2.1. OPT preparation

OPTs were taken from Felda Jengka Pahang aged more than 25 year-old with the consideration that only the samples obtained in the range of 6 feet from the bottom basal was used to reduce the variability of sampling. These OPT sampling were segregate into outer, central and inner regions.

2.2. Air drying process

The samples of OPT core lumber were cut into 5 x 5 x 30 cm dimension. The samples initial moisture are ranges between 150-300% and they were then air dried to reach moisture content about 60 ± 30%.

2.3. Chemical treatment process

OPT core lumber samples were tested on multiple period of dipping in methanol either 5, 10, 15 and 20 minutes.

2.4. Microwave drying process

OPT core lumber samples were placed into microwave oven Panasonic NN-1250W after air dried to desired moisture content. The operating microwave frequency of 2.45 GHz with maximum rated power output of 1000 watt and were varied at 100%, 80%, 60% and 40% power.

2.5. Moisture measurement

OPT core lumber samples moisture content were measured in accordance to British Standard EN323:1993. The samples were cut to cubic of 2 x 2 x 2.5 cm dimension. A digital analytical balance was used to measure the sample weight before and after drying. The samples were dried in an oven of 103 ± 2°C for 24 hours until constant weight was achieved. The moisture content was determined based on the equation (1) below:

\[
\% MC = \frac{(W_o - W_t)}{W_t}
\]  

Where  

%MC = Moisture Content  

W_o = Before drying weight  

W_t = After drying weight

2.6. Microscopic study

The OPTs morphology was investigate using scanning electron microscopy (SEM). The SEM micrographs of vascular bundle and parenchyma were viewed using LEO Supra 50 Vp field emission scanning electron microscope (FESEM) with ultra-high resolution. All samples were gold-sputtered using coater model Polaron SC 515 ± 20 nm to avoid charging.
3. Results and discussion

3.1. Chemical and microwave combination treatment

The moisture content of OPT samples upon combination chemical and microwave treatment was investigated. Moisture content before and after treatment was statistically evaluated via analysis of variance (ANOVA) and the p-value is less than 0.01 indicates that significant different existed. This implies that each of the chemical and microwave treatment combination is possible to significantly reduce the moisture content. Table 1 show the average percentage of moisture reduction content due to various combination treatment.

| Region   | No.   | Microwave power/ % | Methanol Dipping time/ min | Moisture content Before | Moisture content After | Moisture Reduction |
|----------|-------|--------------------|---------------------------|-------------------------|------------------------|--------------------|
| Outer    | N1    | 100                | 5                         | 45.00                   | 21.67                  | 51.84              |
|          | N2    | 80                 | 15                        | 50.00                   | 8.77                   | 82.46              |
|          | N3    | 80                 | 10                        | 48.00                   | 3.40                   | 92.92              |
|          | N4    | 60                 | 15                        | 45.00                   | 10.83                  | 75.93              |
|          | N5    | 60                 | 10                        | 50.00                   | 7.57                   | 84.86              |
|          | N6    | 40                 | 20                        | 40.00                   | 7.83                   | 80.00              |
|          | Untreated |        |                           | 50.00                   | 15.70                  | 68.60              |
| Central  | N1    | 100                | 5                         | 61.80                   | 11.44                  | 81.49              |
|          | N2    | 80                 | 15                        | 80.00                   | 17.70                  | 77.88              |
|          | N3    | 80                 | 10                        | 75.00                   | 4.79                   | 93.61              |
|          | N4    | 60                 | 15                        | 77.50                   | 12.32                  | 84.10              |
|          | N5    | 60                 | 10                        | 67.50                   | 7.72                   | 88.56              |
|          | N6    | 40                 | 20                        | 50.00                   | 8.07                   | 83.86              |
|          | Untreated |     |                           | 56.67                   | 17.88                  | 68.45              |
| Inner    | N1    | 100                | 5                         | 80.00                   | 20.69                  | 74.13              |
|          | N2    | 80                 | 15                        | 90.00                   | 14.22                  | 84.20              |
|          | N3    | 80                 | 10                        | 50.00                   | 3.92                   | 92.16              |
|          | N4    | 60                 | 15                        | 90.00                   | 24.30                  | 73.00              |
|          | N5    | 60                 | 10                        | 85.00                   | 19.12                  | 77.50              |
|          | N6    | 40                 | 20                        | 84.16                   | 9.59                   | 88.58              |
|          | Untreated |     |                           | 90.00                   | 21.75                  | 75.83              |

The maximum moisture content reduction in all was observed when the samples were undergone the N3 treatment with 80% microwave power and 10 minutes methanol dipping time. The moisture content reduction was 92.92%, 93.61% and 92.16% for outer, central and inner regions respectively. On the contrary, it was found that when OPT samples were microwave at treatment of 100% power input and 5 minutes methanol dipping time (N1) the moisture reduction produced show the least percentage for all regions. The least moisture reduction were 51.84% in the outer region, 81.49% in
the central region and 73.00% in the inner region. It is found that the lowest moisture reduction of 73% was obtained under N4 treatment at microwave power input of 60% and 15 minutes dipping time in the inner region while for outer and central region, the maximum moisture reduction is found in N3 treatment with combinations of 80% power and 10 minutes dipping time. The untreated samples moisture reduction is found not correlated to the OPT region. The outer and the central regions shows equivalent moisture reduction at 68.60 and 68.45% respectively whereas in the inner region the moisture reduction is higher at 75.83%.

Based on the previous studies, it is expected that the higher microwave power input as in N1 treatment would give the highest moisture reduction since at higher moisture content will cause increase in sample temperature [6]. However, in this study it is proved that exposure dipping time in methanol also influenced the moisture reduction. This is supported by a study on drying OPT using 85% ethanol concentration showed significant improvement at the higher level [11].

There were three type of chemical treatment process periods that are; a warming-up period which can be characterised by fast rate temperature increases and low rate water loss; an evaporation period is where moisture evaporation rate is the most and the drying temperature reached a constant and a heating-up period where moisture evaporation is low and the fast rate surface temperature increases. In N3, the moderate dipping time of 10 minutes most likely that the volume of water present was evaporated leaving voids within the OPT structure.

The moisture content reduction at moderate and high degrees is depended on the initial wood moisture content, species and energy applied [8]. During chemical treatment, the effect of methanol draw the water from OPT cells allowing the materials to dry. It took about 10 minutes for the microwave heating process to complete. Compare to air drying and kiln drying, this process is much quicker which may take several weeks. The difference of microwave absorbed energy is due to the difference in moisture content inside the bulk of the samples. The process of air drying provided time for wood samples to their moisture content to the environment that is the reason for samples to be air-dried first. The wood had been dried uniformly and shrinkage did not happen when the chemical treatment was done after air drying. Shrinkage do not occur in the samples during the process.

3.2. Morphological effect

The SEM micrograph of parenchyma cell of untreated and treated was compared in Figure 1 (a) and (b). Parenchyma is the lumen of the cells as a carbohydrate storage, thus the starch granules that are embedded clearly in there. It was found that the starch granules are place in the oval laminated lumen cells. The cross sectioned morphology of the parenchyma cells consisted of thick walls of fiber cells and very thin inner cells. The parenchyma cell’s shape was determined by the surrounding cells’ surface tension and/or pressure [12]. Under a total isolation, the cells that assume to be a spherical shape or geometrically perfect can be elongated, curved, flattened or in stellate shapes. Based on the figures, significant change can be detected as untreated OPT was not dense and parenchyma was scattered compared to the treated OPT.
Figure 1. Parenchyma cell of OPT (a) Untreated (b) Treated

Figure 2 (a) and (b) compared the untreated and treated of vascular bundle fibers of OPT. The impurities were found in the surface of the vascular bundle. Vascular bundle also changes as chemical treatment applied vascular bundle was denser compared to untreated OPT. This is because chemical treatment changed the empty space in OPT structure and attracted the bonding between molecule to make it denser.

4. Conclusions
In this study, we can conclude that the combination of chemical treatment on OPT will change the morphological structure. This can also reduce the drying time to make it more cost effective to process treated OPT.

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