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ORIGINAL ARTICLE

# Influence of Torrefaction Parameters on Elemental Properties of Torrefied Oil Palm Empty Fruit Bunch Biochar

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**ABSTRACT** - This study aimed to determine the elemental properties of torrefied oil palm empty fruit bunch (OPEFB) biochar as an alternative renewable energy source. The influence of three major torrefaction parameters namely particle size, holding temperature, and residence time were investigated. This characterization had been done by the elemental analyser. The carbon element in the torrefied OPEFB biochar was increased as the holding temperature and residence time increased from 200–300°C and 30-90 minutes respectively, while the oxygen element amount is decreasing. This is due to the decomposition of hemicellulose that occurred in this region. This shows that torrefaction parameters of holding temperature and residence time influenced in enhancing the energy properties of the torrefied OPEFB biochar by increasing its carbon element and reducing its oxygen element.

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## INTRODUCTION

Nowadays, fossil fuel sources are dwindling, coupled with various types of environmental pollution prompting scientists and researchers to look for other alternative sources that can cover the shortage of fossil fuels. There is now great growth in the quest to find a sustainable and clean energy generation system [1],[2],[3]. Energy demand is always increasing as an effect of global economic development and population growth. Within the next two decades, the world's energy demand is expected to double [4],[5],[6].

The most abundant kind of raw material on the globe is lignocellulosic biomass, which is used in the production of biofuels as well as chemical feedstock [7],[8],[9]. In the body of published work, a variety of studies on the practicability of the generation of bioenergy from biomass derived from forests and agricultural waste in terms of both their economic and environmental viability can be found [10]. As a consequence of this, biomass is a solution that has the potential to be both reasonable and effective in addressing the energy requirements of the globe while simultaneously decreasing dependency on fossil fuels [11], but it needs to go through by biomass energy conversion first and torrefaction is one of them.

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Torrefaction occurs at a temperature of 200 to 300°C, duration below 2 hours with heating rate between 5-15°C/min and in an inert condition, also known as oxygen shortage [12],[13],[14]. The process is influenced by various parameters, including holding temperature, residence time, heating rate, air pressure, particle size, and moisture content. The moisture content of pre-dried biomass samples should be less than 10% before the procedure begins. During the torrefaction process, moisture evaporates, and some of the organic compounds, such as hydrogen and oxygen, are thermally destroyed, resulting in volatile organic molecules [15]. At the same time, this process should reduced the mass of the biomass material without affecting its energy properties. Besides could improving the solid fuel properties of the biomass also known as torrefied biochar by depolymerising long chain polysaccharide.

Therefore, this study was conducted by making the torrefaction process as the biomass energy conversion in characterizing the elemental properties which is carbon (C), hydrogen (H), nitrogen (N), sulphur (S) and oxygen (O) of the torrefied oil palm empty fruit bunch (OPEFB) biochar. There are three major torrefaction parameters that had determined in this study which are particle size, holding temperature and residence time.

## MATERIALS AND METHODOLOGY

### Material

The OPEFB fibre that was used in this study had derived from fibre mill in Seberang Perai, Penang, Malaysia. Then, undergone sun-dried for 24 hours to let it dry and in order to minimize the moisture content of the OPEFB, before the samples were undergoing oven-dried for 1 hour at 80±5°C. After the preheat process, the samples were cut into small pieces to make them easier for grinding and sieving. The sample were ground using blender until it produced fine particles and the screening of the OPEFB was done by using sieve of 250, 500 and 750µm.

### Method

#### *Torrefaction Process*

By using an electrical furnace (muffle furnace of WiseTherm), OPEFB were undergoing a torrefaction process by holding temperature at 200, 250 and 300°C with 30, 60 and 90 minutes of residence times in the absence of oxygen ($O_2$) under a low heating rate about 10°C/min.

#### *Characterization of Elemental Properties*

The analyser model Perkin Elmer 2400 was used for identifying the elemental properties of C, H, N and S elements in percentage. About 2 mg of the samples were weighed before being placed on tin foil, subsequently combusted in a highly oxygenated environment to produce C, H, N, and S elements. Meanwhile, the element of O was calculated by difference of 100% from C, H, N and S.

## RESULTS AND DISCUSSION

Table 1 shows the elemental properties of raw and torrefied OPEFB biochar for each parameter which is particle size, holding temperature and residence time. Generally, elements of C, H and O are the main elements of biomass materials, while elements of N and S are possibly found in small amount. The reaction of endothermic from the dehydration and devolatisation of the OPEFB sample resulting a significant amount of O element decreased like shown in Table 1. This decrement is due to the production of carbon dioxide ($CO_2$) and carbon monoxide (CO) during the torrefaction process occurred [16],[17].

**Table 1**. Elemental properties of torrefied OPEFB biochar

| Weight (mg) | Sample | | | Elemental Properties | | | | |
|---|---|---|---|---|---|---|---|---|
| | Par. Size (μm) | Hold. Temp. (°C) | Res. Time (Min) | C (%) | O* (%) | H (%) | N (%) | S (%) |
| 2.741 | 500 | Raw | Raw | 39.25 | 54.20 | 6.09 | 0.00 | 0.46 |
| 2.758 | 500 | 200 | 30 | 41.09 | 45.43 | 11.88 | 0.00 | 0.98 |
| 2.763 | 250 | 200 | 60 | 42.36 | 44.83 | 11.97 | 0.00 | 0.83 |
| 2.736 | 750 | 200 | 60 | 42.59 | 46.32 | 10.41 | 0.00 | 0.68 |
| 2.817 | 500 | 200 | 90 | 44.12 | 46.38 | 8.93 | 0.00 | 0.57 |
| 2.648 | 250 | 250 | 30 | 44.90 | 44.62 | 9.84 | 0.00 | 0.64 |
| 2.578 | 750 | 250 | 30 | 44.30 | 45.42 | 9.62 | 0.00 | 0.66 |
| 2.741 | 500 | 250 | 60 | 45.07 | 43.05 | 11.03 | 0.00 | 0.72 |
| 2.635 | 750 | 250 | 90 | 45.58 | 42.87 | 10.83 | 0.00 | 0.72 |
| 2.781 | 250 | 250 | 90 | 45.54 | 43.78 | 10.05 | 0.00 | 0.63 |
| 2.886 | 500 | 300 | 30 | 46.44 | 40.87 | 11.90 | 0.00 | 0.79 |
| 2.827 | 750 | 300 | 60 | 47.58 | 40.49 | 11.18 | 0.00 | 0.75 |
| 2.665 | 250 | 300 | 60 | 47.61 | 40.42 | 11.22 | 0.00 | 0.75 |
| 2.292 | 500 | 300 | 90 | 49.83 | 40.94 | 8.55 | 0.00 | 0.68 |

* Calculated by difference

Meanwhile, there are increment for the C element of the torrefied OPEFB biochar along with the increasing of holding temperature and residence time, while the amount of O element is decreasing. This is due to decomposition of hemicellulose [18],[19],[20]. According to Rousset et al. [21], he reported that hemicellulose and cellulose were decomposed at between holding temperature of 250-280°C, where it produces a biochar that contain higher for C element.

The statistical significance of p-value for the C and O elements of the torrefied OPEFB biochar was tested using analysis of variance (ANOVA) as shown in Table 2. From the ANOVA, p-value less than or equal to 0.05 indicates that the parameters are significant. In this case, only holding temperature and residence time showed the significant levels at p-value ≤ 0.05, but not for the particle size. That means both of the significant parameters significantly influenced the C and O elements of the torrefied OPEFB biochar in the manner as discussed above.

**Table 2**. ANOVA for C and O elements of torrefied OPEFB biochar

| Element (%) | Parameter | Mean square | F-value | p-value |
|---|---|---|---|---|
| C | Particle size | 2.112E-007 | 1.688E-005 | 0.9968$^{ns}$ |
| | Holding temperature | 3.59 | 286.53 | 0.0001* |
| | Residence time | 0.42 | 33.79 | 0.0007* |
| O | Particle size | 1.596E-005 | 2.718E-004 | 0.9873$^{ns}$ |
| | Holding temperature | 3.57 | 60.84 | 0.0001* |
| | Residence time | 0.42 | 7.20 | 0.0314* |

The increase in C element of torrefied OPEFB biochar influenced by holding temperature and residence time is also parallel to the fixed carbon increment of proximate properties that had been determined in this study, which also increases as the holding temperature and residence time increase. This is shown by Table 3, where the amount of fixed carbon was increasing with the increment of holding temperature and residence time.

**Table 3**. Fixed carbon of torrefied OPEFB biochar

| Weight (mg) | Sample | | | Fixed Carbon (%) |
|---|---|---|---|---|
| | Par. Size (µm) | Hold. Temp. (°C) | Res. Time (Min) | |
| 2.741 | 500 | Raw | Raw | 4.19 |
| 2.758 | 500 | 200 | 30 | 4.28 |
| 2.763 | 250 | 200 | 60 | 5.87 |
| 2.736 | 750 | 200 | 60 | 7.52 |
| 2.817 | 500 | 200 | 90 | 7.95 |
| 2.648 | 250 | 250 | 30 | 8.03 |
| 2.578 | 750 | 250 | 30 | 8.36 |
| 2.741 | 500 | 250 | 60 | 11.6 |
| 2.635 | 750 | 250 | 90 | 16.79 |
| 2.781 | 250 | 250 | 90 | 14.55 |
| 2.886 | 500 | 300 | 30 | 27.76 |
| 2.827 | 750 | 300 | 60 | 36.03 |
| 2.665 | 250 | 300 | 60 | 36.36 |
| 2.292 | 500 | 300 | 90 | 39.65 |

According to Dhungana [22], this is because torrefaction does not remove any component of ash in the biomass but it helped increasing other components of the biochar and along increased their percentage. In addition, a fixed carbon is one of the important indicators that determine the quality of biochar where good biochar should have a high fixed carbon content as well as C element [23].

## CONCLUSION

As the conclusion, it shown that the C and O were mostly element of the torrefied OPEFB biochar influenced by holding temperature and residence time, but not for particle size. Element of C was increased when higher holding temperature and longer residence time applied, while the amount of O element was decreasing. This is due to decomposition of hemicellulose occurred in this region. This shows that torrefaction parameters of holding temperature and residence time influenced in enhancing the energy properties of the torrefied OPEFB biochar by increasing its C element and reducing O element.

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