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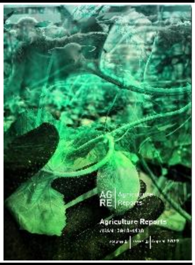

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Effect of Torrefaction Process on Crystallinity Index Properties of Empty Fruit Bunch's Biochar

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Abstract: The effect of torrefaction process on crystallinity index (CrI) properties from biomass material which is empty fruit bunch's biochar had been identified in this study. There are three major torrefaction parameters for biomass material which is particle size, holding temperature and residence time was determined. The investigation on the empty fruit bunch's biochar had been done by X-ray diffraction (XRD). There was decreasing pattern for CrI occurred as the holding temperature increased from 200 to 300°C and residence time increased from 30 to 90 minutes, but there are no significant affected by the particle size parameter. This shows that the empty fruit bunch's biochar cellulose crystallinity is reduced as the cellulose become completely amorphous.

1. INTRODUCTION

Consumptions of fossil fuels drastically shows an interconnection within the population size, industrialization of developing county and the quality of life. By depending on fossil fuels as the energy sources has created the increase of environmental pollution and it sure effects the rate of diminishing fossil fuel sources (Rasat *et al*., 2019). Developed countries mainly are focusing towards sustainable development, which defines as a development that does not compromise the needs of the future generations. Utilization of efficient energy and renewable energy are the possible solution towards the current environmental issues which will help in achieving an optimistic future energy with least possible of environmental problems.

In Malaysia, the main energy use for production of energy were mainly comprised of coal, petroleum, oil and natural gas products (Chong *et al*., 2015). The production from combustion of fossil fuels produced various toxic gases, droplets of tar, soot and ashes and organic compound that released to the air and that leads to a huge consequences of climate change and pollution which will affects humans' lives and the ecological balance of the planet (Tomlin, 2021). Therefore, it is necessary to shift from non-renewable fossil fuels towards the usage of renewable energy sources such as biomass which be found from organic waste, crops, herbaceous and woody that gives a more convenient ways of energy production.

In Malaysia, there is about 168 million tonnes residues coming from such municipal solid waste, oil palm waste, and rice husks every single year (Ozturk *et al*., 2017). Biomass sources from the palm oil mill in Malaysia is abundant in energy by utilizing the oil palm waste such as empty fruit bunch (EFB) and palm kernel shell (PKS). They could be as potential sources in generating energy especially by biomass thermochemical energy conversion (Abdullah & Sulaiman, 2013) and torrefaction is kind of the thermochemical technique that can enhance the utilization and conversion efficiency of biomass sources.

Torrefaction can be defined as a biomass treatment in the thermal range between 200 to 300°C with heating rate between 5 to 15°C/min for duration below than 2 hours in a non-oxidising environment (Rasat *et al*., 2020). This process will produce three products in different forms and one of them as torrefied biochar in solid form. This solid form were produced by the drying and partial devolatization of the biomass material during torrefaction process with reducing the mass of biomass without affecting the energy content, besides improved the solid fuel properties of biomass by depolymerising long chain polysaccharide and removing carbon dioxide (CO_2) and water (H_2O).

Thus, by taking torrefaction process as an advantage, this study was conducted to determine the crystallinity index properties of the torrefied EFB biochar to be as an alternative renewable energy sources. The effect of three major torrefaction parameters which is particle size, holding temperature and residence time was investigated in determining the crystallinity index properties of torrefied EFB biochar undergo by XRD.

2. MATERIALS AND METHODS

The EFB fibre that being used in this study had derived from fibre mill in Seberang Perai, Penang, Malaysia was undergone sun-dried for 24 hours to let it dry and in order to minimize the moisture content of the EFB, the sample were undergoing oven-dried for 1 hour at 80±5°C. After the preheat process, the sample were cut into small pieces to make it easier to grind and sieved. The sample were grind using blender until it produced fine particles.

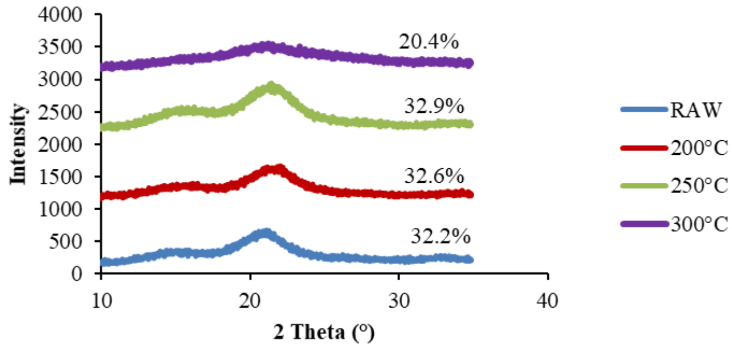
By using an electrical furnace (muffle furnace of WiseTherm), EFB were undergoing a torrefaction process by holding temperature at 200, 250 and 300°C with 30, 60 and 90 minutes of residence times in the absence of oxygen (O_2) under a low heating rate about 10°C/min.

A XRD machine model Bruker D2 Phaser patterns with monochromatised Cu Kα radiation (λ= 1.5406Å) had been used in determining the crystallinity index of the sample. The XRD machine were generated at 45kV and current of 30mA. The raw and torrefied EFB biochar samples were prepared in powder form through grinding and sieving until the size is less than ~10μm, before going for scanning in ranges of 2θ from 10 - 90° at 38.4s. The powdered samples were packed and the surfaces were flattened in a sample holder, then inserted into sample positions and were ready for the testing.

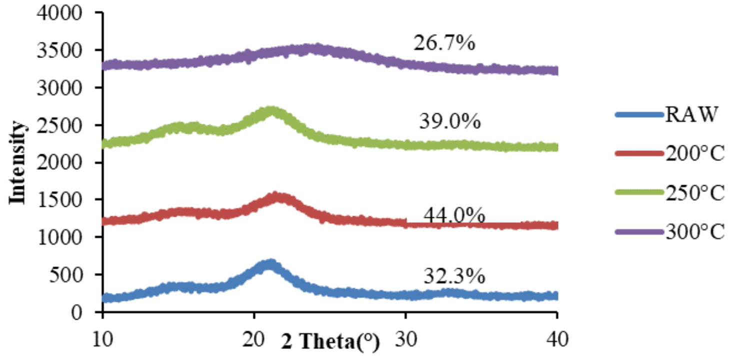
3. RESULTS AND DISCUSSIONS

The changed of the crystallinity of torrefied EFB biochar is shown by Figure 1 below on raw and torrefied EFB biochar at different holding temperature for each residence time. The control of EFB has crystallinity index (CrI) of 32.2%. As the study progress with the increase of holding temperature for 200 and 250°C at 30 minutes, the CrI increased from 32.6 to 32.9% due to the degradation of hemicellulose and the amorphous cellulose was partly crystallised due to thermal treatment before it degraded at higher temperature (Wen *et al*., 2014). According to Liang & Wang (2017) however had reported that partial carbonization had been occurred at 220°C at 4 hours of residence time, thus making the peak shifted and the strength weakened as the higher holding temperature increased.

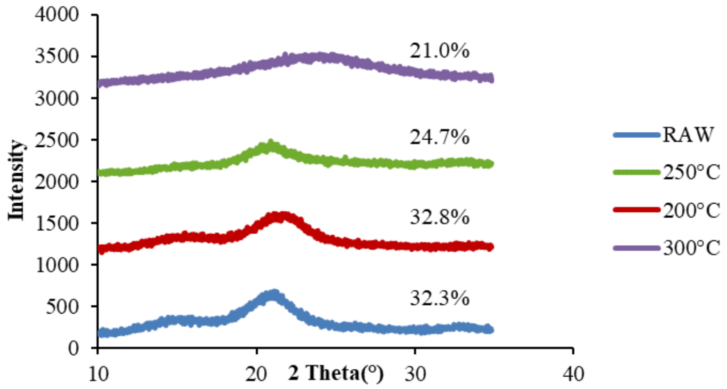
This CrI decreasing pattern on each of the torrefied EFB biochar can be seen in Figure 1(a), (b) and (c) as holding temperature and residence time increased from 200 to 300°C and 30 to 90 minutes respectively, suggested as the amorphous cellulose was partly recrystallised due to the thermal treatment that limited devolatisation and carbonisation in hemicellulose where depolymerisation and recondensation occurred in lignin and cellulose. This shows that the crystallinity of the torrefied cellulose is disappearing, and the cellulose becomes completely amorphous by the torrefaction before degradation occurred at higher temperature (Neupane, 2015). This indicates that the crystallinity of the torrefied cellulose disappeared, and the cellulose becomes completely amorphous by the torrefaction (Wannapeera & Worasuwannarak, 2015).



(a) 30 minutes of residence time



(b) 60 minutes of residence time



(c) 90 minutes of residence time

Figure 1: The crystallinity index of torrefied EFB biochar

4. CONCLUSION

As a conclusion, the CrI of torrefied sample that has been decreased as the holding temperature increase from 200 to 300°C indicates the cellulosic depolymerisation and degradation occurred during the heating process (Zhang *et al.*, 2022), plus increasing the residence time from 30 to 90 minutes absolutely. This shows that the crystallinity of the torrefied cellulose is reduced as the cellulose become completely amorphous and as a suggestion, densification into pelletized may results in a more energy-dense product. Study on the effect of torrefaction process on the grindability behaviour and energy content of it also could be done.

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