CHAPTER 3

Microwave-Assisted Pyrolysis as an Advanced Technology for Biochar Production from Lignocellulosic Biomass Conversion

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3.1 INTRODUCTION

Pyrolysis is one of the thermochemical conversion technologies to convert biomass into value-added products such as syngas, bio-oil, and biochar. The processing method is performed in oxygen-deficient conditions at moderate temperatures (400-600 °C) (Foong et al., 2020). The pyrolysis process can be classified into flash, fast and slow pyrolysis depending on the temperature, pyrolysis time, and heating rate generating a varied range of product yield (Foong et al., 2020). The operating pyrolysis parameters can be manipulated to obtain the specific and higher conversion of product yields. For such, the low reaction temperature with slow heating rate and prolonged pyrolysis time may favour biochar production. Meanwhile, bio-oil and syngas yield can be maximized with a higher heating rate and rising pyrolysis temperature.

Biochar is a carbon-rich material with a highly porous fine-grained structure produced from the pyrolysis process. Much interest and research have focused on the development of biochar using an advanced microwave pyrolysis technology for agricultural and environmental applications. As the biomass sample subjected to microwave radiation produces a better biochar product with a higher surface area, porosity, and aromaticity structure (Haeldermans et al., 2019). Additional studies on the pyrolysis parameter must be in-depth analysed to acquire the optimal condition for the high quality of biochar. The present review specifically summarizes the pyrolysis technology for biochar production using microwave pyrolysis method. A comprehensive understanding of the fundamental heating of microwaves was focused. Then, the factors that influence the yield and properties of the microwaved biochar including microwave power, microwave absorber, carrier gas flow, and pyrolysis time are discussed as future directions to produce high quality and selectivity biochar.

3.2 FUNDAMENTALS OF MICROWAVE HEATING

Microwave heating is a non-contact energy transfer process from electromagnetic energy evenly into thermal energy. The heat is transferred directly to the sample under microwave irradiation which implying fast heating rates. As the material may transmit, reflect, or absorb microwaves radiation dependent on the characteristics of the material (Mello et al., 2014). Besides, the volumetric heating characteristic of microwaves also may heat the treated material uniformly. The oscillation fields of microwaves include a magnetic field and an electric field as shown in Figure 3.1. The rotation of molecules due to high operating frequency can generate heat while providing enough penetration depth of the microwaves into the materials.

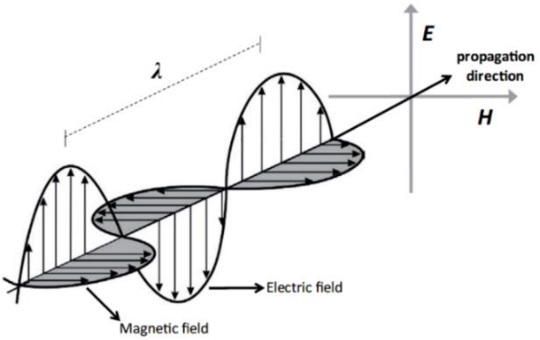

Figure 3.1 The electric and magnetic field components in microwave (Mello et al., 2014)

Microwave heating is classified as a sub-category of dielectric heating. The heat can be generating from microwave energy as dielectric material experience dipolar polarization and ionic conduction. The dipolar polarization and ionic conduction mechanism are depicted in Figure 3.2 (a) and Figure 3.2 (b). The microwave irradiation of a sample causes water and polar fluid molecules to rotate and align rapidly in both induced and permanent dipoles with an alternating field known as dipolar polarization as shown in Figure 3.2 (a). The increasing molecular motion generates friction and collision which can cause heat loss and microwave heating. If the frequency field is much higher than the dipole response time, there is no heating occur as the dipole does not have sufficient time to realign (Bilecka & Niederberger, 2010). The dissolved charged particles in ionic conduction also collide with each other to the orientation of the electric field illustrated in Figure 3.2 (b) converting kinetic energy into heat which results in a temperature rise. The ionic conduction