CHAPTER 2

THERMAL AND MASS TRANSPORT BY PULVERISED PALM BIOMASS DURING TORREFACTION

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2.1 INTRODUCTION

Malaysia has wide substantial potential for biomass energy utilisation given its equatorial climate which is ideal for tropical forest growth and also agricultural vegetation. In Malaysia, there are five main biomass waste that contribute from tropical and agricultural: rice cultivation (0.7%), sugar cane cultivation (0.5%), forestry (wood products) (3.7%), municipal solid waste (9.5%) and the largest sectors, oil palm cultivations (85.5%) as shown in Figure 2.1. Approximately, 14% of the 340 million barrels of oil equivalent of energy used per year have been contributed by biomass in Malaysia according to Chuah et al. (2007).

Palm oil is the paramount commodity in Malaysia, playing a pivotal role in transforming the landscape of its agriculture and economy. Despite the rapid production, the oil palm industry become the main sector that generates abundant biomass as renewable sources including empty fruit bunch (EFB), mesocarp fibre (MF), palm kernel shell (PKS), oil palm fronds (OPF) and oil palm trunks (OPT). Palm kernel shell is a high lignocellulosic biogenic waste generated from the processing of crude palm oil. The shell part is obtained after removed the nut and crushed it in the palm oil mill. Palm kernel shell is also a highly fibrous material, high lignin, hemicellulose and silica containing ash which can lead the product to have high heating value.

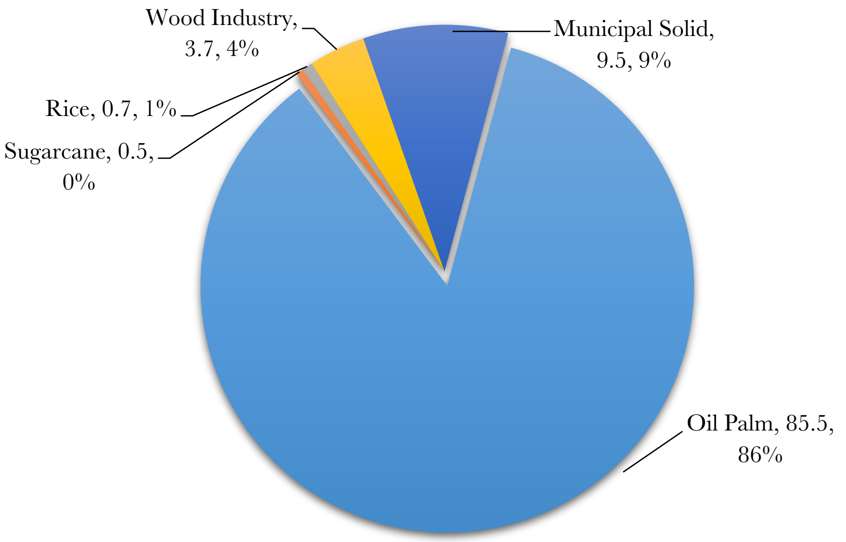

Figure 2.1 Biomass waste distribution in Malaysia (Source: Shahbaz et al., 2016)

On the other hand, according to Faizal et al. (2018), the main purpose of torrefaction is to improve the properties of the biomass for better application. The torrefaction process can be classified into three categories based on temperature levels: light level (200 °C to 235 °C), mild level (235 °C to 275 °C), and severe level (275 °C to 300 °C). The global demand for torrefied goods in Malaysia has significantly risen, particularly from energy making industries in Korea and Japan. This is due to the excellent performance of solid fuel derived from biomass, which yields high-quality syngas through gasification and bio-oils through the pyrolysis process. Moreover, the process of torrefaction can improve both the fuel and physical transport properties of the treated biomass. The products from torrefaction possess improved grind ability and have high heating value as well as low moisture uptake capacity and molecular compositional oxygen/carbon (O/C) and hydrogen/carbon (H/C) ratios.

Meanwhile, drying in torrefaction is accomplished by vaporizing and removal of water or moisture from a product to form a dry solid. The heat is obtained from its surroundings by convection, radiation and conduction or by internal generation such as dielectric and microwave. Drying media can be in terms of flue gas, hot air or superheated steam. In this process, the body of the product will evaporate the moisture while the carrier gas will receive the vapor by latent heat of vaporisation that is supplied to the body which involves heat transfer and mass transport process. According to Severini et al. (2004), the efficiency of a drying process is influenced by various aspects, including the mode of heat transfer, whether the process is continuously or discontinuously, the direction of the heating fluids in relation to the product, and the pressure (atmospheric, low, deep vacuum). Table 2.1 shows the comparison of properties of raw palm kernel shell regardless of its particle size that have been done in previous study by Mohd Najib (2020). In this study, the most critical part of the palm kernel shell properties is moisture content (%) which affected the properties of pulverised palm biomass during the drying process.

Table 2.1 Properties of raw kernel shell (Source: Naqila, 2020)

Parameter	Value
Moisture Content, %	9.74
Ash, %	9.64
Fixed Carbon, %	16.45
Volatile Matter, %	64.17
C, %	36.26
H, %	4.47
N, %	0.41
S, %	0.22
O, %	58.37
HHV (MJ/kg)	16.08