

EFFECT OF TORREFACTION ON OIL PALM EMPTY FRUIT BUNCH PELLETIZATION

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ABSTRACT

This paper focuses on the properties of raw and torrefied pellet from EFB by varying different parameters including energy consumption, moisture adsorption, Meyer hardness test and pellet density. To save storage space and transport costs, it can be compressed into fuel pellets of high physical and energetic density. The pelletizing properties were determined using single pellet press and pellet stability was determined by compression testing.

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Pelletization of raw and torrefied empty fruit bunch (EFB) from compression single pellet press (SPP) was investigated to quantify the energy consumption and pellet properties including moisture adsorption, pellet density and Meyer hardness. Energy consumption for torrefied EFB pellet were significantly higher than those for raw EFB pellet, while the moisture adsorption rate of torrefied EFB pellets increased with increasing the severity of torrefaction.

Keywords: oil palm empty fruit bunch (EFB) torrefaction; pelletization.

1. INTRODUCTION

Torrefaction is a pre-treatment process where biomass is heated in the absence of oxygen at low heating rates which is less than 50°C/min to temperatures between 200°C and 300°C to produce a darkened material with improved chemical and physical properties. The moisture and oxygen-rich volatile materials with low calorific value are driven off will result in a reduction in hydroxyl groups that can form hydrogen bonds with moisture and a greater mass loss to energy loss producing a more energy dense fuel during torrefaction [5]. Torrefaction of biomass accompanies weight loss depends on torrefaction conditions. During torrefaction of biomass, most volatile compounds are removed from biomass vapors and result in a higher energy density. In addition, the advantages of torrefaction include higher calorific value or energy density, lower moisture content and better grinding [3].

Few studies have been published in recent years, focusing on how to make a pellet from different biomass [8] but to the best author knowledge none have studied in detail on how to make a quality pellet from raw and torrefied EFB. There were many challenges to utilize the raw biomass due to its characteristic. This is because the raw biomass is usually high in moisture content, low energy density, difficult to store and poor grind ability [2]. It also is bulky and inhomogeneous materials that make it difficult to comminute into small particle [6]. Some studies produced torrefied pellets from other biomass such as oil palm mesocarp fiber (PMF). Pelletizing properties of torrefied biomass have been analyzed depending on torrefaction conditions [3]. The biomass have been milled, dried and mechanically densified during pelletization to enhancing its heating value and burning characteristics [1]. In this

study, EFB was used to carry out a study on physical and mechanical properties of raw and torrefied pellet. The effects of pellets from raw and torrefaction conditions on the physical properties and mechanical properties from raw and torrefied EFB was successful characterized.

2. METHODOLOGY

2.1. Sample Preparation of Raw and Torrefied EFB

The raw sample weighed of 200g was dried inside the oven for about two hours at 105°C at 24 hours. This method is to remove the whole moisture content from the EFB. The preparation for sample of raw, the sample were grinded and sieved at 3 sizes which is 250µm, 500µm and 750µm while for the preparation of torrefied sample, 500µm of EFB was required in this process. After that, torrefaction temperature of the sample that put inside the microwave [10] were 200°C, 225°C, 250°C, 275°C and 300°C and then the residence time that setting in this process at 3 time which is 20, 40 and 60 minutes with continuous purge of 30ml/min nitrogen gas. The selected power that was used in this process is 100, 230, 385, 540 and 700W. 500µm and 15g of EFB that was required while conducting this process to have the effect [11] of heating rate on different power, temperature on power selection, magnetron on power selection, power on fractional torrefied biomass and temperature on mass loss was recorded to choose the best selected power. The main reason to choose the best selected power because of the best power will produced the torrefied material. Besides that, it also to proven either this biomass can be used as renewable energy. The schematic diagram of pellet mold based as shown Fig. 1.

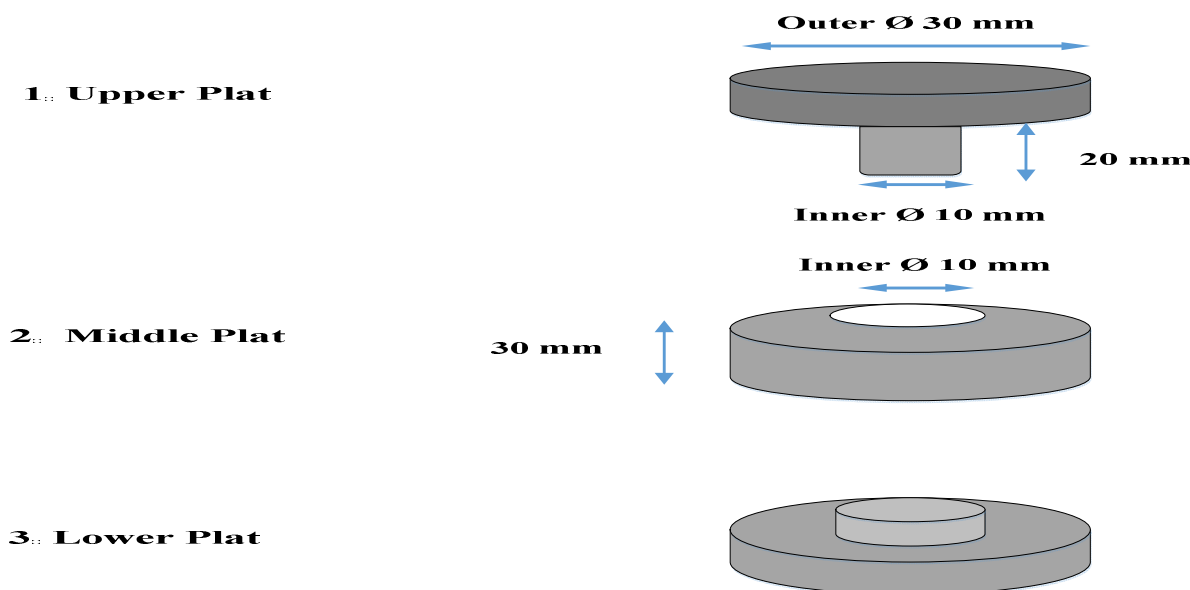


Fig.1. Schematic diagram of pellet mold

2.2. Pelletization of Raw and Torrefied Pellet and Product Analysis

For the preparation of pellet from raw EFB, the biomass was loaded in pellet mold, not exceeding 1g per layer which is at 3 different size, 250 μ m, 500 μ m and 750 μ m for 0.60g, 0.55g and 0.50g respectively. While for the preparation of pellet from torrefied EFB, 500 μ m of EFB size was loaded in pellet mold in 0.70g with 10% of glycerol as a binder agent for different temperature and residence time which is 200 $^{\circ}$ C, 250 $^{\circ}$ C and 300 $^{\circ}$ C and 20, 40, 60 minutes. When the all sample was prepared, the process of compression pellet was conducted. The sample was compressed with a maximum pressure of 200 MPa at rate of 5mm/min using a Universal Testing Machine (UTM), equipped with a maximum 5 kN load cell and an electronic data collection system. And then, the pressure was released after 5 seconds, the piston removed and a new amount of sample is load and compress until the pellet had desired dimensions. The sample was pressed by applying a force 1kN-5kN for raw sample and then for torrefied sample 1kN and 5kN.

In this study, the raw and torrefied pellet were made and used to determine the physical and mechanical properties of pellet. The Meyer hardness against compression from a static indentation test was measured. When a force is applied to the pellet, the pellet will be deformed. The Meyer hardness (H_m) defined as the static indentation hardness was

determined from the applied force, probe diameter and indentation depth as Equation (1).

$$H_m = F / [\pi (Dh - h^2)] \quad (1)$$

where h is indentation depth; F is the force ; and D is the diameter of rod. Meyer hardness was reflects the resistance of the solid object to various kinds of permanent shape changes when an axial force is applied. To calculate the energy consumption, forces and displacement was recorded to form the pellets. The decomposition of hemicellulose and lignin reduced the plasticity of sawdust, contributes to the increased energy consumption during the compression and extrusion. The single pellet density was calculated from measured mass and volume of individual pellet. The strength of pellets was measured 24h after production. Before the strength measurement, dimensions (length and diameter) and mass of each pellet was measured using weighing balance and for the volume was measured by vernier calipers to calculate pellet density. The density or more precisely the volumetric mass density of a substance is its mass per unit volume. For moisture adsorption testing, the sample was dried in an oven at 30°C for 2 hours. After that, the sample was placed in climatic chamber at 30°C and 90% of relative humidity. After moisture absorption in climatic chamber, the moisture uptake was measured as the weight difference between the initial dry weight and the equilibrated weight.

3. RESULTS AND DISCUSSION

3.1. Appearance Study of Raw and Torrefied EFB Pellets

Table 1 shows the appearance of raw pellet while the appearance of torrefied pellet was shown in Table 2. The pressure force that have been used for the raw pellet, 1kN until 5kN while for the torrefied pellet, only 1kN and 5kN. For pelletizing torrefied pellet, glycerol have been used and also act as binder agent.

Table 1. The appearance of raw EFB pellets on different force



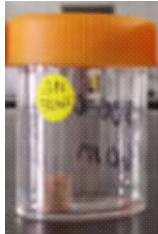












Sample	Pellet				
	1kN	2kN	3kN	4kN	5kN
 500mic					

Table 2. The appearance of torrefied EFB pellets on different force

Sample	PELLET (with Glycerol 10% as Binder Agent)	
	1kN	5kN
 200°C (20min)		
 250°C (20min)		
 300°C (20min)		

3.2. Meyer Hardness

The average Meyer hardness was measured for selected pellets, with average results shown in Fig. 1a and b. Fig. 1a shows that the hardness of raw sample decreased with increasing of particle sizes. The highest hardness of raw sample is at 250mic with force 5kN which is 10.77N/mm^2 , while the lowest hardness is at the sizes 750mic with force 1kN which is 2.20N/mm^2 . Fig. 1b shows that the hardness of torrefied sample decreased with the increasing of degree of torrefaction and residence time. The highest hardness of torrefied sample is at 200°C with the residence time 20min and 5kN force which is 9.71N/mm^2 , while the lowest hardness is at 300°C with the 60min residence time and different force, 1kN which is 1.80N/mm^2 . For comparison, the hardness of torrefied sample is lower than raw sample. Due to the amount of available hydrogen bonding sites is reduced during torrefaction. So, the strength of torrefied pellets is lowered compared to pellets made from untreated sawdust as shown in previous research [9].

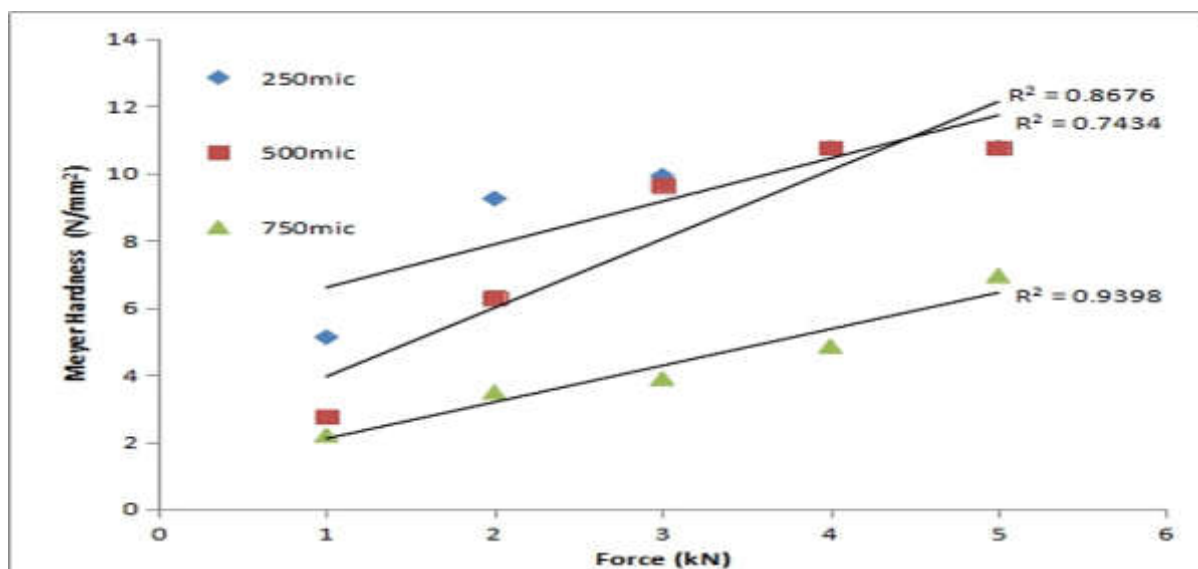


Fig.1a. Meyer hardness of raw EFB pellets

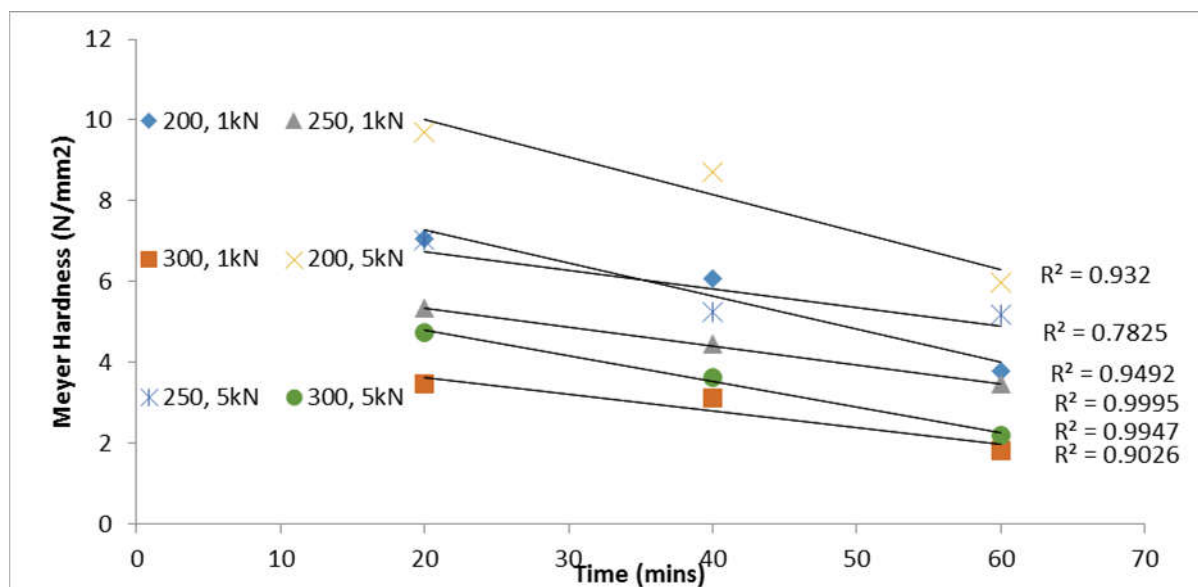


Fig.1b. Meyer hardness of torrefied EFB pellets

3.3. Energy Consumption

Energy consumption associated with compression of single pellet for raw and torrefied EFB pellets are presented in Fig. 2a and b respectively as a function of force, torrefaction temperature and residence time. The trend data analysis of raw and torrefied EFB pellets in Fig. 2a and b shows increased trend with wide ranges of sizes and densities. Higher energy input is needed to densify the torrefied EFB pellets than raw EFB pellets, and the energy requirement increases with increasing the degree of torrefaction. Early study showed the torrefied EFB could not be pelletized without glycerol, compared to pelletized raw EFB. Higher die temperature is needed to make a rigid torrefied pellets. Fig. 2a shows the highest energy consumption of raw sample at 750mic and 5kN force which is 80.68 kJ/kg, while the lowest energy consumption of raw sample at 250mic and 1kN force which is 11.24 kJ/kg. Fig. 2b also shows the highest energy consumption of torrefied pellet at 300°C with the residence time 60min and 5kN force which is 97.01 kJ/kg, while the lowest energy consumption of torrefied pellet at 200°C with the residence time 20min and 1kN force which is 19.01 kJ/kg. For comparison, the torrefied sample consume more energy than raw sample to be pelletized the pellet.

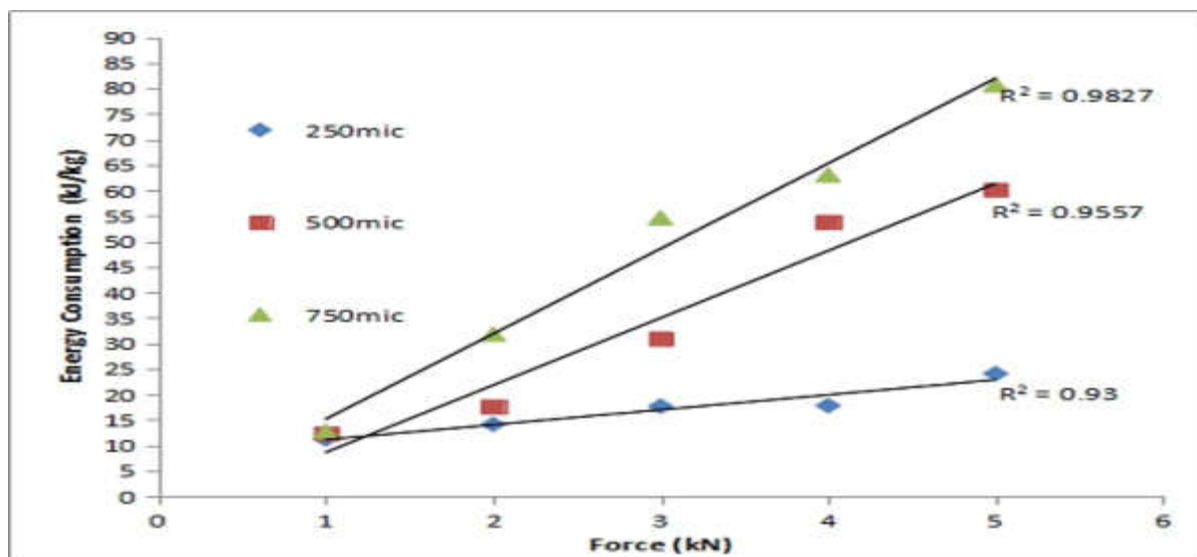


Fig.2a. Effect of energy consumption raw EFB pellets

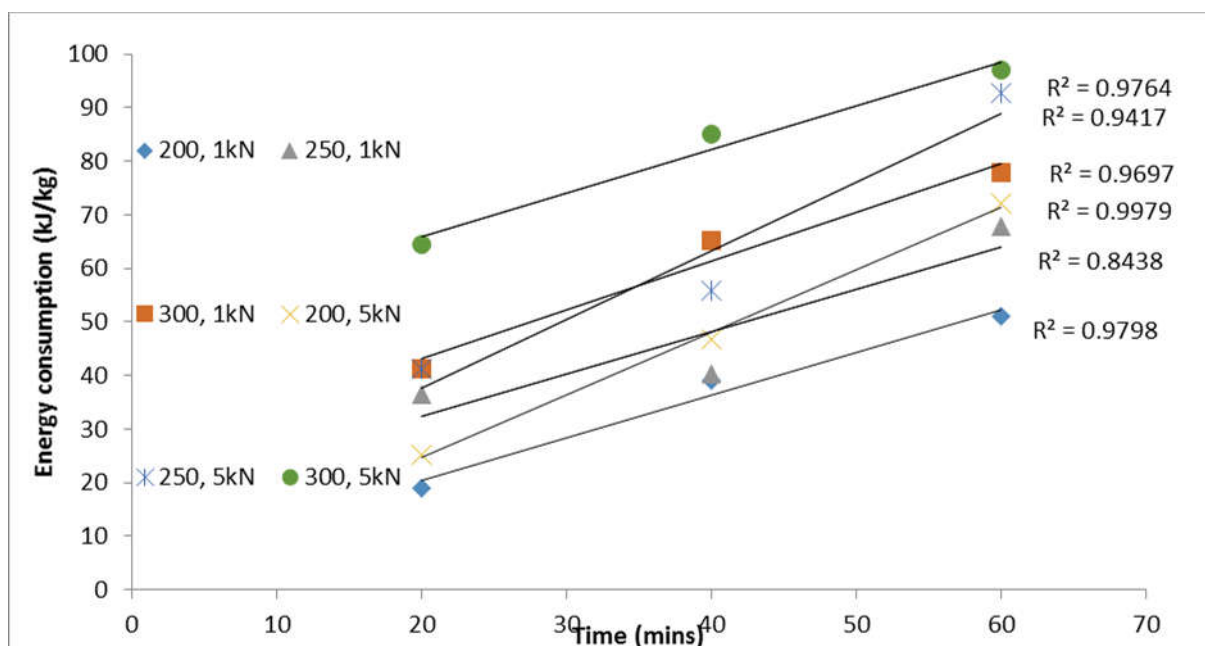


Fig.2b. Effect of energy consumption torried EFB pellets

3.4. Pellet Density

Fig. 3a shows at the same force, the density rate decreased with increasing of particle size of EFB. The results from this study agreed well with the previous work as done by [7]. They found that the pellets made from lower particle size exhibited higher density for all biomass. The highest density of raw EFB pellet is is 907kgm³, while the lowest density of raw pellet is 623kgm³. In the past research, the higher compaction pressure or higher die temperature is required to increase the density of torried pellets. The trend data analysis [12] shows the

density of torrefied EFB pellets in Fig. 3b decreased with increasing of degree of torrefaction temperature at the same residence time. As shown in the previous the reason why decreasing of pellet density is mainly related to the loss of chemically bonded water and low-melting point compounds which act as a binding agent when softened at 100°C. In previous research, density of torrefied EFB pellets must be lower than raw EFB pellets due to loss of chemically bonded water and low melting point compounds during torrefaction [4]. However, the result shows the highest density of torrefied EFB pellet is 974kg/m³, while the lowest density of torrefied EFB pellet is 574kg/m³. For comparison, the torrefied sample shows the low density compared with raw sample.

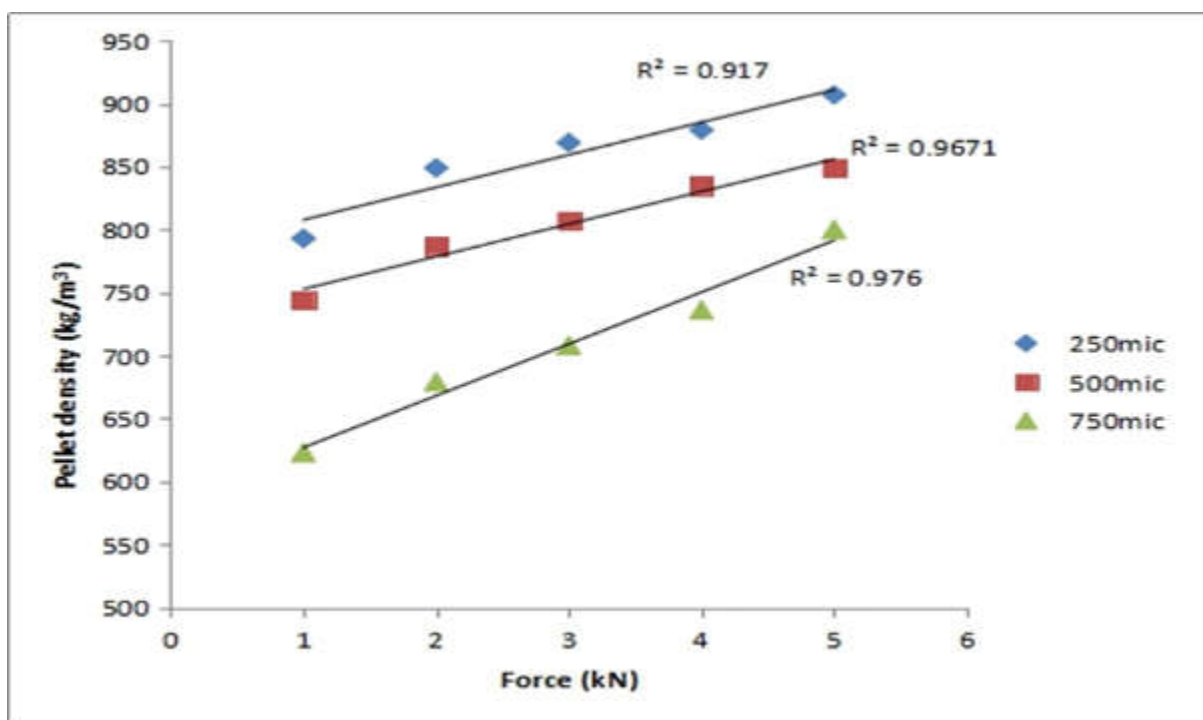


Fig.3a. Density of raw EFB pellets

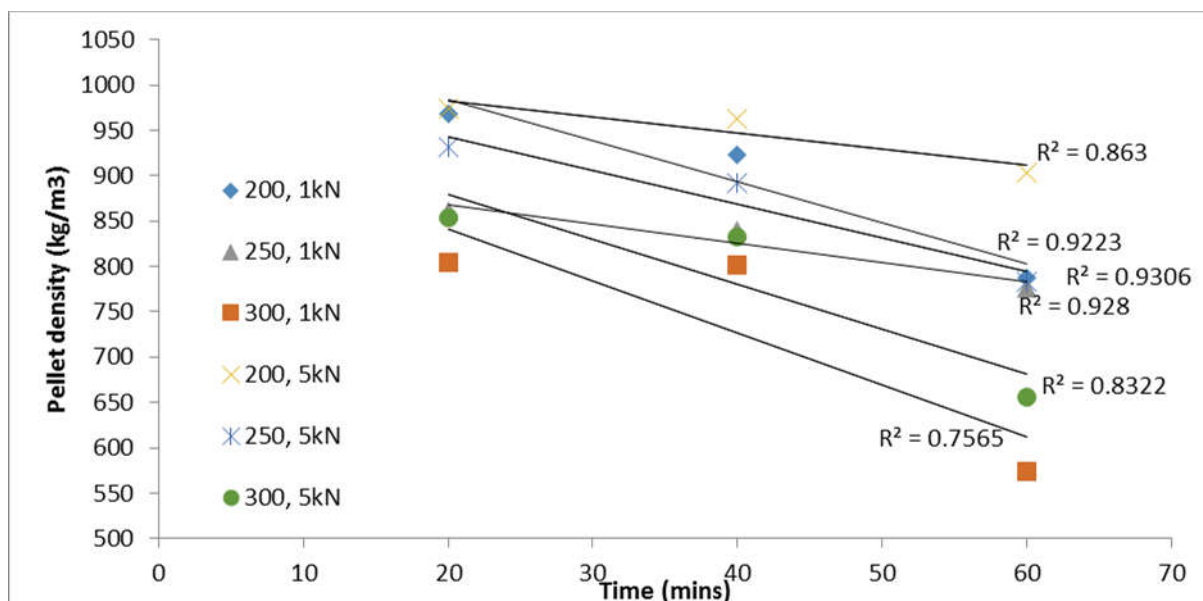


Fig.3b. Density of torrefied EFB pellet

3.5. Moisture Adsorption

Moisture adsorption by dry the pellets at 30°C in oven for 2 hours was measured, with the average results shown in Fig. 4a and b. It is seen that the moisture adsorption capacity of EFB decreased significantly after torrefaction. Fig. 4a shows at the same sizes the water adsorption rate decreased with the increasing of force. The result shows the high moisture content of raw sample at 250 mic with force 1kN which is 10.38 wt% but as shown in previous research [8], the high moisture content above optimum it gives negative effect on pellet density. Meanwhile, the low moisture content of raw sample at 750 mic with force 5kN which is 3.57 wt%. Fig. 4b also shows that at the same degree of residence time, the water adsorption rate decreased only slightly with increasing the torrefaction temperature, likely associated with the slight difference in the structure and composition of torrefied biomass [13]. The result shows the high moisture content of torrefied sample at 200°C with the residence time 20min and force 1kN which is 5.91 wt%, while the low moisture content at 300°C with the residence time 60min and force at 5kN which is 0.09 wt%. For comparison, the moisture adsorption of torrefied sample is lower than raw sample and as shown in previous research [3], the advantages of torrefaction includes higher calorific value or energy density, lower moisture content and better grinding.

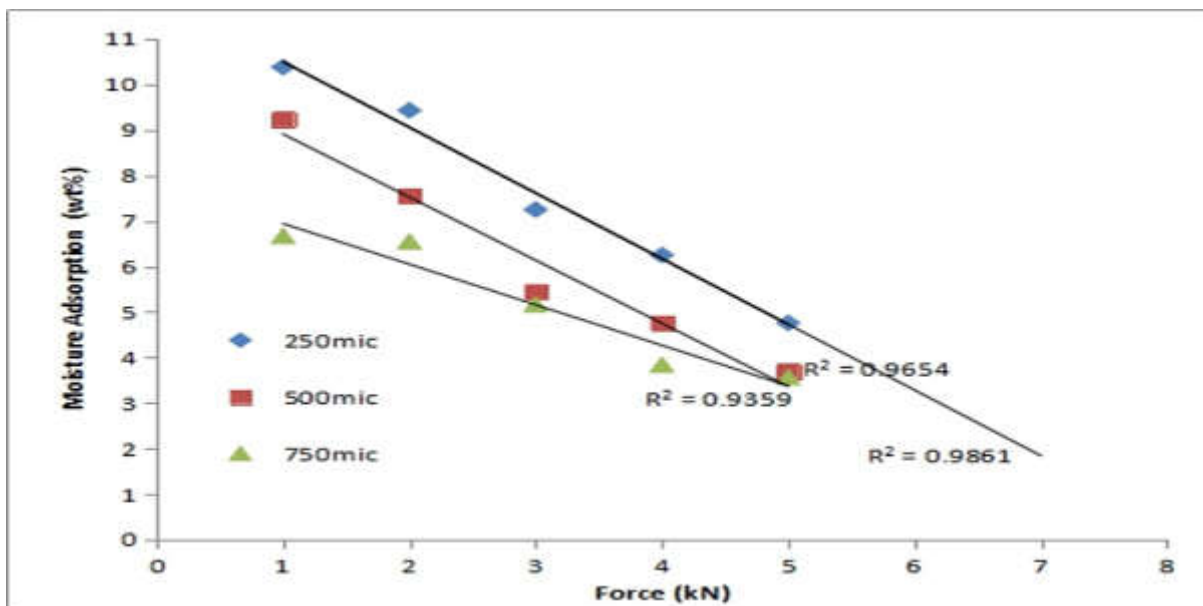


Fig.4a. Effect of weight loss on moisture adsorption raw EFB pellets

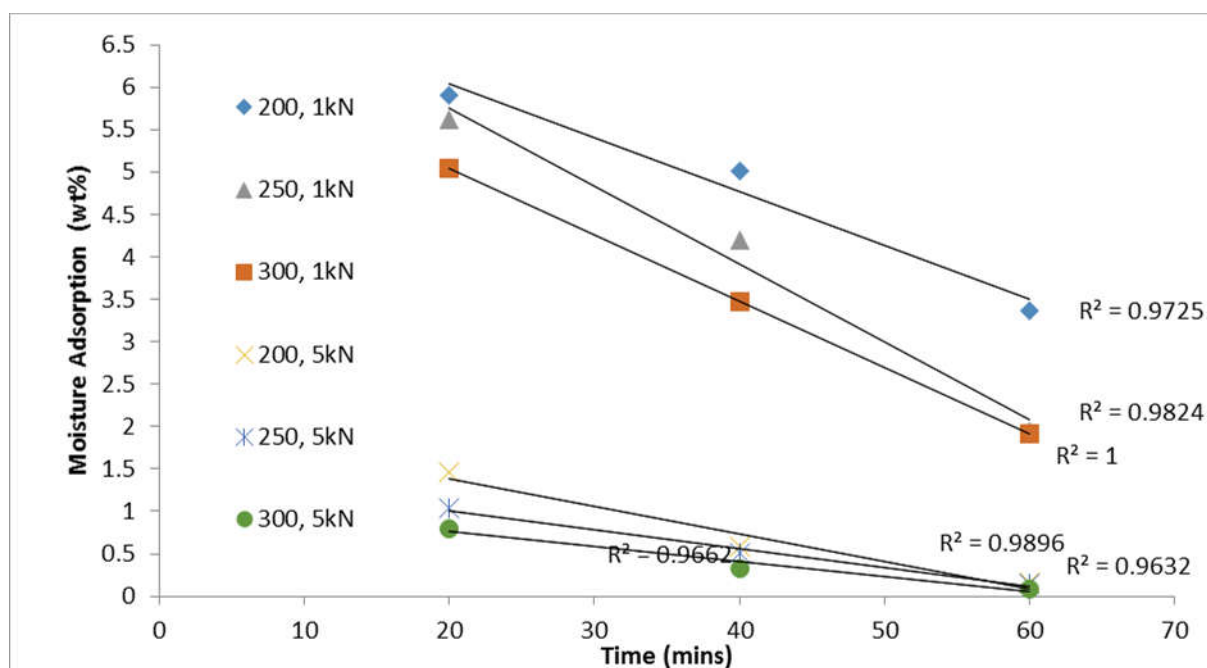


Fig.4b. Effect of weight loss on moisture adsorption torrefied EFB pellets

4. CONCLUSION

The pelletization process of raw and torrefied EFB produced from Universal Testing Machine (UTM) by single pellet press (SPP) and the compression testing was used to identify the energy consumption and pellet properties. Energy consumption of torrefied sample were significantly higher than raw sample at the same pelleting condition. The density of torrefied pellet was higher than raw pellet, while the torrefied pellet density decreased with increasing

degree of torrefaction temperature and residence time. The hardness of pellet was reduced in the torrefaction process, while the hardness of pellets increased with the increasing of torrefaction but for the increasing residence time, the hardness becomes decreased. However, the moisture adsorption of torrefied pellet was lower than pellet from raw sample, while the moisture adsorption of torrefied pellets increased with increasing the severity of torrefaction.

5. ACKNOWLEDGEMENTS

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