ORIGINAL ARTICLE

Effect of Pellet Size and Adhesive Ratio on the Production of Kenaf Pellet as a Fossil Fuel

S. Krishnan[1,2]*, M. Nasrullah[3], S. Mohamad[4]

[1]Department of Civil and Environmental Engineering, Faculty of Engineering, Prince of Songkla University, Songkhla, Thailand.
[2]School of Civil Engineering, Faculty of Engineering, University of Technology Malaysia (UTM), Skudai, 81310, Johor Bahru, Malaysia.
[3]Faculty of Civil Engineering Technology, Universiti Malaysia Pahang (UMP), Lebuhraya Tun Razak, 26300, Gambang, Kuantan, Pahang, Malaysia.
[4]Faculty of Chemical and Process Engineering Technology, College of Engineering Technology, Universiti Malaysia Pahang, 26600 Pahang, Malaysia.

ABSTRACT – This research presents an investigation on the pellet size and adhesive ratio towards the production of kenaf pellet. The examined operating parameters were pellet size (2 - 3 cm) and adhesive ratio (0 - 15 wt%). The sample was densified through hot and cold molding press machine at 130 °C and 7 MPa. The analysis of the pellet was done through scanning electron microscope (SEM) analysis, calorific value, and combustion analysis. SEM analysis was used to study the surface morphology of the different starch content in kenaf pellets. The best surface recorded was the pellet with a 2.5 cm diameter at 10 wt% starch ratios as it shows clearly the structure of the starch. Calorific value analysis was recorded and the highest value obtained for the pellet with 15 wt% of starch is 46.2 kJ/kg. The highest mass yield for the pyrolysis process was achieved for the pellet at 15 wt% starch content. Pellet production is useful for fossil fuel in exchange for coal as it is more environmentally friendly and classified as renewable energy. Besides, pellet form can be conveniently used for storage and transportation.

INTRODUCTION

Coal which finds its application in combustion may be 20% more costly than biomass, however coal is responsible for the production of the most carbon emissions and other pollutants than any other fuel source. Carbon dioxide (CO_2) released from the burning of coal increases the level of greenhouse gases emission. The alternative way to reduce the reliability on coal as fuel source is the utilization of biomass [1]. Biomass can be used to reduce the dependability on coal as one the fuel sources. Because of that, the level of CO_2 released to the environment decreases. The utilization of biomass for heat and power production becomes increasingly important, due to the desire to reduce CO_2 emissions to the atmosphere. Plant biomass is available in large quantities, and can be utilized for sustainable heat and power production, when used as fuel [2]. Kenaf plant or scientific name Hibiscus cannabinus L is in the family Malvaceae, is strong, fibrous trees resembling okra in terms of leaves and flowers. Kenaf is a warm season annual fiber crop [3]. It also an annual herbaceous fiber plant that are common in wild plant of tropical and subtropical Africa and Asia which has grown for several thousand years for food and fibers [4].

For the transportation and handling, additional cost is incurred if long distant logistic is required. Plant materials and woods in general have porous structure that result in low densities ranging from 40-150 kg/m³ for grass type biomass [5] and 320-720 kg/m³ for most types of dried hard- and softwoods [6]. The density of the biomass can be increased by compressing it into pellets using a mechanical process, in which pressure is applied to the biomass to crush its cellular structure, and thereby increasing its density [7]. By making it more compact, the caloric value can be increased, contributes to the reduction in space requirement and reducing the brittleness of the fiber.

Pelletization process facilitates the boost of energy density, lower the transportation and storage costs. Secondly, it allows automatic feeding to the domestic and industrial sized boilers. The increasing industrial and domestic demand for heat and power production from biomass in various countries has resulted in a strong growing global pellet making during the last decades, and continuous growth of the market is predicted for the next years [8, 9]. As a result, the increasing production of pellet biomass from year to year is recorded. In this work, the production of kenaf pellet was conducted at different pellet diameters (2 – 3 cm) and starch ratios (0 – 15 wt%). The produced pellets were characterized in terms of mass yield after combustion analysis, calorific value and morphology through scanning electron microscopy (SEM).

MATERIALS AND METHODS

Chemicals

Kenaf fiber (*Hibiscus cannabinus L., Malvaceae*) was collected at Lembaga Kenaf Malaysia at Indera Mahkota, Pahang, Malaysia. The adhesive used was the commercial Tapiocca starch flour which can be purchased at the nearest store. The samples were dried at the open air to maintain the moisture at the samples surface and then, ground to form a powder like-size (in range of 2 mm).

Pelletization Procedure

Kenaf powder and starch flour were homogenously mixed together with different ratios: 100 wt% Kenaf+ 0 wt% starch, 95 wt% Kenaf + 5 wt% starch, 90 wt% Kenaf + 10 wt% starch and 85 wt% Kenaf + 15 wt% starch. Then, the blended raw mixture was inserted and pre-compressed manually into the mould. The pre-compressed mixtures in mould were then compressed up to 7 MPa (at 130℃) by using hot press machine for about 10 minutes. After the compression process completed, the Kenaf pellets were removed from the mould and left to cool to room temperature.

Characterization

Combustion analysis of the Kenaf pellet was carried out using a furnace for 30 and 60 minutes at 300 °C with the heating rate of 10 °C/min. 10 grams of Kenaf pellet was weighted and placed in the furnace and the weight of combustible sample was recorded to determine the mass yield using Equation 1 [10].

$$Mass\ yield = \frac{Mass\ pellet\ after\ combustion}{Mass\ pellet\ before\ combustion} \times 100 \tag{1}$$

The calorific values of the Kenaf pellet were measured using bomb calorimeter. The surface morphology of the different starch ratio in kenaf pellets were investigated using scanning electron microscope (SEM) Carl Zeiss Evo 50.
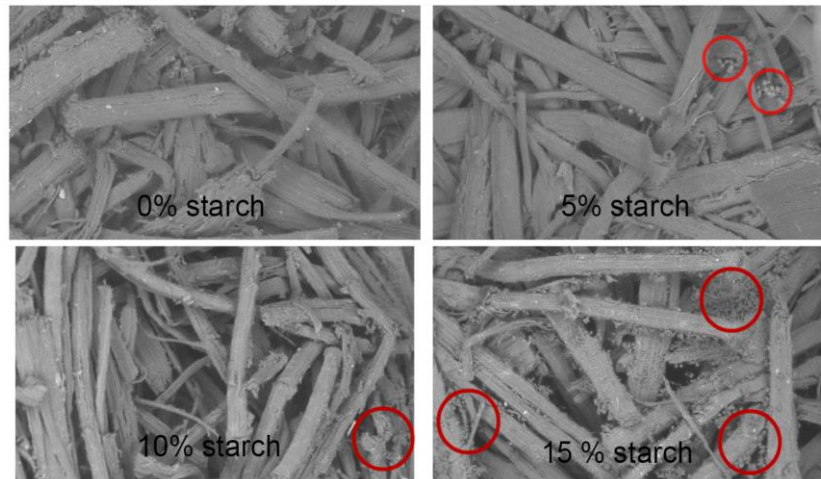
EXPERIMENTAL RESULTS

Physical characteristics of kenaf pellets

After the pelletization process, the samples physical characteristics were compared as illustrated in Figure 1.
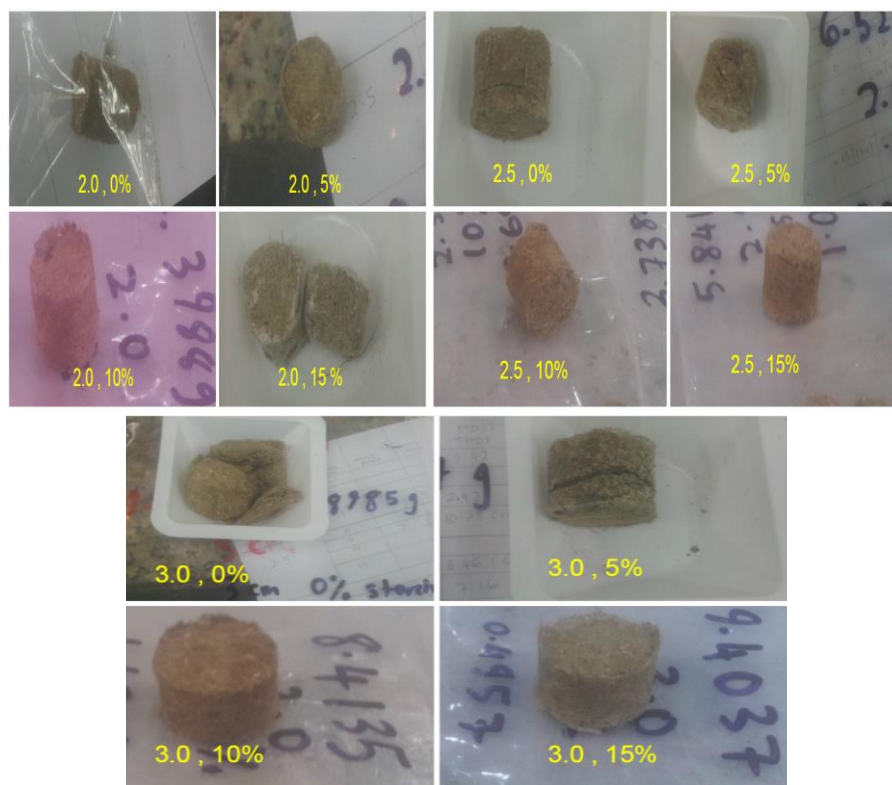
Figure 1. Physical appearance of Kenaf pellet at diameter 2.0, 2.5 and 3 cm for starch ratio 0-15 wt%.

Figure 2. Morphology (100x magnification) of kenaf pellets (2 cm) at different starch ratios.

The pellets with the diameter of 2 cm show higher stability and strenght (hard to crack) compared to pellets with 2.5 and 3 cm diameter. Most of the produced pellets with 3cm diameter are fragile and unable to withstand high pressure. Starch is added to improve the bonding between fibers which result in more stable pellets were produced. In this work, the ratio of starch was set to 0 wt%, 5 wt% 10 wt% and 15 wt%. For 0 wt% pellets, the fiber easily falls off and unable to withstand the exerted force. Therefore, it is hard to maintain the shape and acceptable calorific value.

The 5 wt% starch content demonstrated better physical characteristics than the 0 wt% starch pellets. It was found that the 2 cm diameter produced pellet gives the best result. For 10 wt% pellet, the fiber was very compact, not easily disintegrated and break. The produced pellet also exhibits resistance to break when manually pressed unless a high force is applied, which makes 10 w% starch content a more suitable ratio for the pellet. The pellet with 15 wt% of starch showed low ressitance and hardness against 10 wt% of starch content. Therefore, 10 wt% starch content is selected as an optimized starch content ratio for the pellet, creating all necessary bondings between kenaf fibers during the pelletization process.

The microscopic analysis of kenaf pellet on the surface morphology is important in characterizing the physical structural of pellet (see Figure 2). From the morphology, it can be seen that the structure of starch is very small within a round shape. The pellets with 5 - 15 wt% starch (red circle) contains starch particles around the kenaf fiber. Next, the arrangement of kenaf pellet were not closely compact as there are many spaces between kenaf fiber.
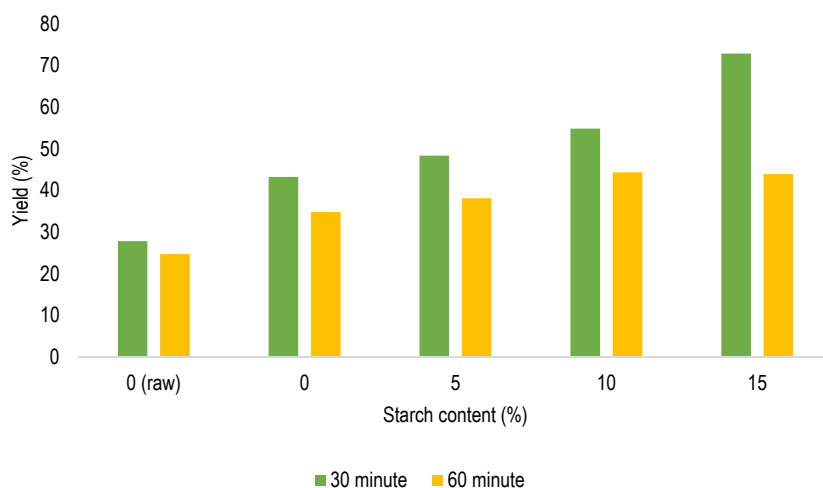
Calorific value

Figure 2 illustrates the energy values of the kenaf in powder (raw) and pellet forms with different starch contents. The highest calorific value was the pellet with 15 wt% starch ratio and the lowest is the powder kenaf. It can be observed that the higher ratio of starch generated higher the calorific value of pellet. Starch acts as adhesive which increases the strength bond between kenaf. Based on Figure 2, the bonding strength increases as the starch ratio increases. The difference of the calorific value between 0 and 5 wt% starch pellet is higher which is 7.99 MJ/kg. When the 5 wt% pellet was compared to the 10 wt% pellet, the change in value is not high, only 4.13 MJ/kg. Similar trend was also reported for the pellets with 15 wt% and 10 wt% starch ratios, the change is only 1.89 MJ/kg. Based on the differences recorded, the calorific value obtained, at some point, is maintained despite of the increment in starch ratio.
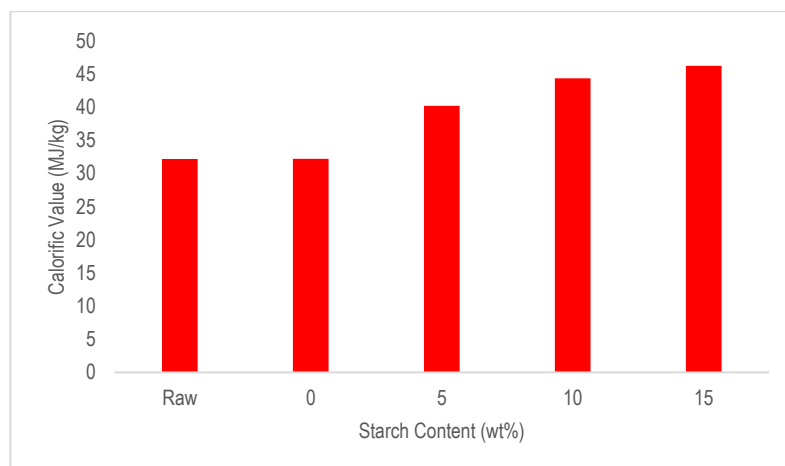
Figure 3. Calorific value of kenaf powder (raw) and pellet at different starch contents.

Mass yield

Figure 3 shows the mass yield data against the starch content for 30 and 60 minutes of combustion. Mass yield increases as the starch content in kenaf pellet increases for 30 minutes of combustion. Whereas for 60 minute-combustion, mass yield increases to nearly 10% for pellet with 10 wt% and 15 wt% starch. This finding can be explained by understanding the ability of the starch to hold kenaf more tightly as compared to kenaf pellet with no starch content. Such recognized ability may reduce the mass loss during pyrolysis process. Based on the calculated mass yield, the optimum starch content is 10 wt%, because the low starch content kenaf pellet is observed to potentially produce equivalent yield similar to high starch content of kenaf pellet.

Figure 3. Mass yield of kenaf pellets at 30 and 60 minutes of combustion process.

CONCLUSION

The calorific value data showed that the amount of starch content in the pellets is directly proportional to the calorific value of the pellets. The calorific values of pellets increase rapidly from no starch content to 10 wt% starch content and only slightly increase from 10 wt% to 15 wt% starch content in the pellets. Other than that, the 10 wt% starch content has the ideal physical characteristic as the fiber will not fall off easily and the pellets will not stick on the mold because of the starch content exceed the ideal proportion. In conclusion, the pellet with diameter of 2 cm and 10 wt% starches exhibit the best characteristics for the energy application.

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