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Effect of mixing ratios on physical properties and energy consumption of leucaena pellets by using fermented cassava-rhizome

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ABSTRACT

The purpose of this research was to study the effect of mixing ratios of binder on the properties of leucaena (*Leucaena leucocephala*) pellets. In this study, the fermented cassava-rhizome was used as a binder in the production of leucaena (*Leucaena leucocephala*) pellets. The duration time of the fermentation process was three days. The mixing ratios of leucaena with fermented cassava-rhizome varied at 90:10, 80:20, 70:30, 60:40, and 50:50, respectively. The results demonstrated that the mixing ratios of binder affected the bulk density and durability of leucaena pellets. The increasing amount of fermented cassava-rhizome increased the bulk density and durability of leucaena pellets. The physical properties were determined following the Pellet Fuels Institute standard specification for residential/commercial densified fuel. Moreover, the results illustrated that the optimal mixing ratios (leucaena: fermented cassava-rhizome) in the production process of pellets was 70:30, as this mixing ratio provided the lowest energy consumption (420 kWh/ton) in pellets production and the highest mass yield at 94.3%. Thus, the results obtained from this research suggested that the fermented cassava-rhizome as a binder might be an alternative adhesive material for improving the asymmetrical structure and physical properties of biomass raw materials

***Keywords*:** leucaena; fermented cassava-rhizome; mixing ratio; physical properties

1. INTRODUCTION

Thailand is a well-known agricultural country due to its abundant agricultural products. Further, Thailand has a large amount of agricultural residues, which are important sources of biomass energy, a type of renewable energy. The biomass fuel is one of the primary energy sources for cooking and heating. Biomass is created from agriculture residues and waste products; these are rice husk, straw, sugarcane bagasse, corncob, palm leaf, and leucaena (Prasertsan and Sajjakulnukit, 2006; Barz and Delivand, 2011; Intagun and Tharawadee, 2016; Intagun et al., 2018). Leucaena (*Leucaena leucocephala*) is one of the interesting agricultural residues because of its high calorific value. *Leucaena leucocephala* is known in Thailand as "krathin tree", a leguminous tree belonging to family Fabaceae, which is a fast-growing plant and found displeasingly in nutrient-poor soil across the country. This tree is used for a variety of purposes, such as firewood, fiber, and livestock fodder. Because of its fast-growing and high yield of biomass production, it is selected as a candidate as raw material for pelletizing biomass. Twigs of kratin tree, after their leaves are removed (as for food and animal feed), contain high holocellulose content with low lignin and high heating value (Chotchutima et al., 2013; Posom et al., 2016; Singh et al., 2017; Rattawan et al., 2019, Izzati et al., 2019). Moreover, cassava-rhizome is an important waste product from agricultural residues, considered for producing renewable fuels in Thailand. Cassava (*Manihot esculenta*) was cultivated as an annual crop in many tropical countries, including Thailand. After the removal of the starchy tuberous roots, the residual cassava leaves and immature rhizome are sun-dried and used as cassava hay (Warajanont and Soponpongpipat, 2013; Martin et al., 2017). Because cassava-rhizome contains high fermentable carbohydrates such as starch, cellulose, hemicellulose, and lignin, it renders support to the growth of several microorganisms, as well as it can be a binder for biomass materials (Wei et al., 2015; Zhu et al., 2015). The demand for biomass fuels in Thailand for electricity production has kept on increasing every year as the price of biomass fuels is cheaper than fossil fuels. Furthermore, biomass energy can help to reduce the greenhouse effect. However, the cost of transportation and storage of these raw materials are significantly high due to the low bulk density and asymmetrical shape of biomass. One of the solutions to these problems is to compact the biomass materials (pelletizing or palletization) by densification technology. Densification technology is the process of increasing the density of biomass to enhance combustion efficiency. The direct use of biomass materials is impacted by many factors such as the difference in shape and low weight per volume resulting in reduced combustion efficiency. Therefore, due to low weight per volume, the biomass materials must be compressed to increase the weight per volume for efficient utilization. Biomass pellets are used to replace fuels and natural gas because they are renewable and do not pollute the environment. The densification process of pressing a material into the shape of a pellet can improve the symmetrical property, bulk density (approx. 5-7 times), and durability of these raw materials (Mani et al., 2006; Kaliyan and Morey, 2009; Hurun and Afzal, 2016; Garcia-Maraver et al., 2015). The market demands of biomass pellets have been increasing every year in Thailand. The main parameters affect the pellet quality were particle size, moisture content, additives, and binder (Mani et al., 2006; Kaliyan and Morey, 2010; Gil et al., 2010; Ahn et al., 2014; Jiang et al., 2016; Izzati et al., 2019; Kanoksilapatham et al., 2020). The binder addition could improve the important properties of biomass pellets such as bulk density, durability, and combustion characteristics. Furthermore, pellets formation will help in safe storage and proficient transportation. The chemical contents such as cellulose, hemicellulose, lignin, and a small amount of adhesive binder improve the quality of pellets, and reduce processing energy consumption (Liu et al., 2013; Berghel et al., 2013; Liu et al., 2016; Rattawan et al., 2019). This research aims to analyze the influence of mixing ratios of the fermented cassava-rhizome binder on leucaena pellet's physical properties (bulk density and durability). Further, the effect of mixing ratios on energy consumption during pellets production and mass yield of pellet were studied. The results from this research will be very helpful to select an effective mixing ratio of fermented cassava- rhizome to improve the properties of pellets and provide guidelines for the energy consumption analysis for a larger scale of pellet production on a commercial basis.

2. MATERIALS AND METHODS

2.1 Materials

Leucaena (*Leucaena leucocephala*), or twigs of kratin tree after their leaves are removed (for food and animal feed) were the main raw material of biomass. The rhizome of cassava was the natural binder in this study. Both biomasses were obtained on May 2019 from Cha-um district, Phetchaburi province, Thailand, and Ban-pong district, Ratchaburi province, Thailand, respectively. The raw material and binding agent were ground and sieved in which the particles of leucaena and cassava-rhizome were 5 mm. The initial moisture content of the ground leucaena (10%-12%) and cassava-rhizome (12%-14%) were determined. The images of the ground particles of leucaena and cassava-rhizome are shown in Figure 1.


(a) (b)

Figure 1 The main raw materials: (a) leucaena (*Leucaena leucocephala*), (b) cassava-rhizome (*Manihot esculenta*)

2.2 Pellet fuel production processes

The pellet fuel production process consists of drying, grinding, pelletizing, and cooling. After the drying process, the pellet size of leucaena and cassava-rhizome will be around 5 mm and pellets were ground by using a grinding machine. The cassava-rhizome as a binder was added with water to obtain a final water content of 22% of the total solid mass and fermented for three days. To study the effect of mixing ratio (leucaena: fermented cassava-rhizome) on physical characteristics such as bulk density and durability value on leucaena pellets, various mixtures are analyzed and fermented cassava-rhizome as the binder were supplemented with mixing ratios at 90:10, 80:20, 70:30, 60:40, and 50:50, respectively in the preparation of mixing pellets. Moreover, the effect of binding type on the leucaena pellet quality was investigated with; (1) leucaena without binder (L) or control condition, (2) leucaena with non-fermented cassava-rhizome (LNFC); and (3) leucaena with fermented cassava-rhizome (LFC). The biomass blend pellets were produced using a flat-die pellet mill machine (KL200B Model, China). During pelletizing process, the die temperature was at 70°C-80°C. The raw materials were pressed through the flat die by pan grinder roller. The pellets were placed in the room temperature for 24 h before they were subjected to pellet fuel qualification testing. The pellets diameter was 6.0±0.1 mm. Finally, the pellet fuel samples were tested according to Pellet Fuels Institute (PFI) standard specification for residential/commercial densified fuel.

2.3 Pellet fuel quality testing

This study used the PFI standard specification for residential/commercial densified fuel to verify the physical properties. The bulk density and durability of biomass pellets are very important indicators to evaluate substantial storage facilities, spaces, and handing systems. The higher bulk density and durability of pellets leads to higher transport efficiency and lower storage space. The pellet bulk density testing procedure followed the ASTM E-873-82. Biomass pellet bulk density was calculated using the following Equation (1).

$$\rho_{bulk} = \frac{W_b}{V_b} \tag{1}$$

where ρ_{bulk} is the bulk density of pellets in (g/m^3), W_b is the total weight of the pellets (g), and V_b is volume of the standard box (m^3).

The durability of pellets represents the inter-particle bonding in the pellet, which indicates the strength and structure of pellets. This parameter affected the stability of pellet products during transportation and effectiveness of the pellets. The durability testing is evaluated by the tumbling method following the EN 15210-1 regulation. The pellets of 500 g were put into the test box and rotated at 500 rpm for 10 min. Later, the pellets sample were removed and sieved. The mass of pellets before and after sieving was measured. Then, the durability was calculated by Equation (2).

$$PDI = \frac{WPW}{IW} \times 100 \tag{2}$$

where PDI is pellets durability index, WPW is the total mass of the pellets after tumbling (g), and IW is mass of pellets before tumbling (g).

2.4 Energy consumption and mass yield of the pelletizing process

In this study, the energy consumption of the flat-die pellet mill machine during the pelletizing process was calculated. The energy consumption was influenced by binder addition. The energy consumption was recorded by using a watt-hour meter. The weight of pellet samples before and after the pelletizing process was measured by a digital scale (EM-150KAL). The energy consumption of the pelletizing process was determined by Equation (3).

$$EC = \frac{E_{use}}{W_f} \tag{3}$$

where EC is energy consumption of the pelletizing process (kWh/kg), E_{use} is total energy used in pelletizing process (kWh), and W_f is final weight of pellet samples (kg).

In addition, the mass yield (Y_m) of biomass pellets was the proportion of mass used as input for feeding the machine, and after processing by the flat-die pellet mill machine, the mass yield is calculated from the Equation (4).

$$Y_m = \frac{M_T}{M_O} \times 100 \tag{4}$$

where Y_m is mass yield (%), M_T is the mass of the samples before pelletizing (g), and M_O is the mass of the samples after pelletizing (g).

3. RESULTS AND DISCUSSION

3.1 Effect of mixing ratios on physical appearance of leucaena pellets

The physical appearance of leucaena pellet products was illustrated in Figure 2(a-f). The sample of leucaena without fermented cassava-rhizome (100:0) has small cracks on the outer surface and a rougher texture, which reveals the low quality of pellets. In comparison, it was found that the pellet products from LFC at mixing ratio of 90:10, 80:20, 70:30, 60:40, and 50:50 revealed a more smooth texture and shiny appearance than the mixing ratio of 100:0. The physical appearance of the pellet samples was very smooth with a shiny texture. This quality is increased with increase in the fermented cassava-rhizome content. The pellet texture in the case of using fermented cassava-rhizome as a natural binder led to the glassy surface of the pellets compared to without binder case. Moreover, the physical appearance of the pellet product was quite dark-colored with an increase in the fermented cassava-rhizome contents. Therefore, the addition of the fermented cassava-rhizome as a natural binder demonstrated that the mixing ratios of binder affected the physical appearance of leucaena pellet products.


(a) 100:0

(b) 90:10

(c) 80:20

(d) 70:30

(e) 60:40

(f) 50:50

Figure 2 Effect of mixing ratios on physical appearance of leucaena pellets (a) 100:0, (b) 90:10, (c) 80:20, (d) 70:30, (e) 60:40, and (f) 50:50

3.2 Effect of mixing ratios on bulk density of pellets

The effect of mixing ratios (leucaena: fermented cassava-rhizome) on the bulk density is revealed in Figure 3. The results showed that the bulk density of leucaena pellets without fermented cassava-rhizome (100:0) as reference samples was 652.24±2.54 kg/m^3. The bulk density of LFC at the ratios of 90:10, 80:20, 70:30, 60:40, and 50:50 were 663.17±2.32 kg/m^3, 665.22±3.65 kg/m^3, 679.54±5.12 kg/m^3, 682.31±4.39 kg/m^3, and 689.42±3.76 kg/m^3, respectively. The bulk density of all samples was in a range of the PFI standard (609-737 kg/m^3) and so the values were accepted. It was illustrated that the bulk density of LFC was significantly higher than leucaena pellets without fermented cassava-rhizome. The mixing ratio with fermented cassava-rhizome at 50:50 had the highest bulk density of pellets. Furthermore, the results showed that the increase of natural binder at mixing ratio of 90:10, 80:20, 70:30, 60:40, and 50:50 increased the bulk density of leucaena pellets by 1.68%, 1.99%, 4.19%, 4.61%, and 5.71%, respectively. Thus, the bulk density of leucaena pellets increased with an increase in fermented cassava-rhizome content of the mixture. The bulk density of mixture fuels with a binder (fermented cassava-rhizome) was higher than the leucaena without binder because of the higher bonding between particles of fermented cassava-rhizome that were created mainly through solid bridges during leucaena pellet production. The natural binding components such as starch in fermented cassava-rhizome can be activated under high temperatures in the pelletizing process (Garcia-Maraver et al., 2015). The chemical compositions or compounds present in biomass (cellulose, hemicellulose, and lignin) behave as a natural binder binding the biomass particles. Moreover, the biomass was crushed out to the cell of biomass due to the high pressure developed during the densification process (Liu et al., 2013). The results of this study are similar to the previous work (Liu et al., 2016), which investigated the pellet physical properties of mixing biomass between bamboo and rice straw. Therefore, it was confirmed that the fermented cassava-rhizome as a natural binder has improved the bulk density of leucaena pellets.

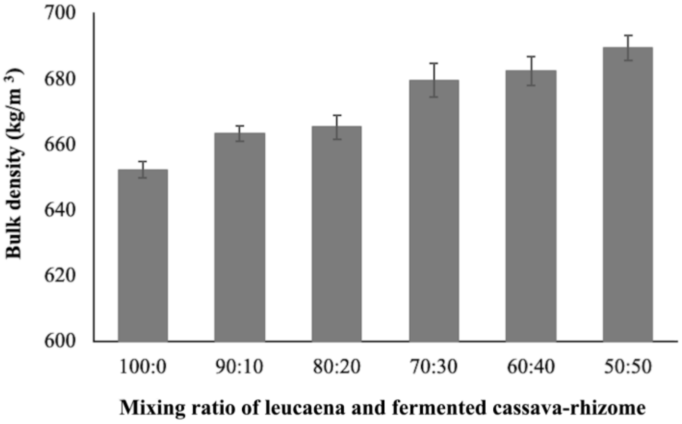

Figure 3 Effect of mixing ratios of leucaena and fermented cassava-rhizome on bulk density of pellets

3.3 Effect of mixing ratios on bulk density of pellets

This research evaluates the effect of mixing ratios on the durability of pellets. The pellet durability of leucaena with the different mixing ratios of fermented cassava-rhizome is shown in Figure 4. The durability of leucaena without fermented cassava-rhizome (100:0) was 94.12±0.35%, which was not within the requirement of PFI standard (≥95%). The pellets durability values of mixing ratios (leucaena: fermented cassava-rhizome) at 90:10, 80:20, 70:30, 60:40, and 50:50 were 95.81±0.5%, 96.63±0.2%, 97.38±0.8%, 98.32±0.3%, and 98.65±0.5%, respectively. Then, these values revealed that the mixing ratios of binder affected the durability of leucaena pellets. The results demonstrated that the addition of a binder fermented cassava-rhizome results in pellets with higher durability as compared to leucaena without a binder. Moreover, the durability of pellets gradually increased as the fermented cassava-rhizome quantity was increased. This is due to the bonding mechanisms of the binder, as starch in fermented cassava-rhizome acts as a binding agent (Kaliyan and Morey, 2010). Moreover, this result corresponds with the previous research, which studied the effect of binder on the durability of wood pellets fabricated from *Larix kaemferi* C. and *Liriodendron tulipifera* L. sawdust (Ahn et al., 2014). Thus, it was concluded that the durability of leucaena pellets had improved through the mixing leucaena and fermented cassava-rhizome.

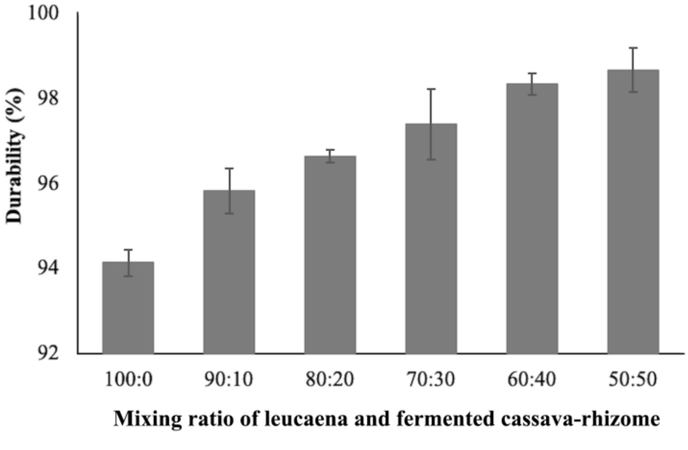

Figure 4 Effect of mixing ratios of leucaena and fermented cassava-rhizome on durability of pellets

3.4 Effect of binding types on physical properties of leucaena pellets

To evaluate the effect of binder types on the leucaena pellet quality, the two natural binder types namely LNFC and LFC with duration time of three days were selected. All the pellet samples were prepared, in which the mixing ratio of 50:50 case (of leucaena: natural binder type) was considered. The effect of natural binder type on the bulk density and durability of leucaena pellets is shown in Figure 5. It was illustrated that the physical properties of leucaena pellet with a binder (LNFC and LFC) were significantly higher than leucaena pellet without a binder (L). Moreover, the physical properties of LFC had revealed higher values than the LNFC. It had been observed that the highest pellet bulk density and durability was with the LFC, due to the fermentation process for a binder that can help the performance of natural binding components under high temperature during the pelletizing process (Liu et al., 2013). Therefore, the result was illustrated that the LFC case is the best binder type in this research because it can improve the bulk density and durability of leucaena pellets.

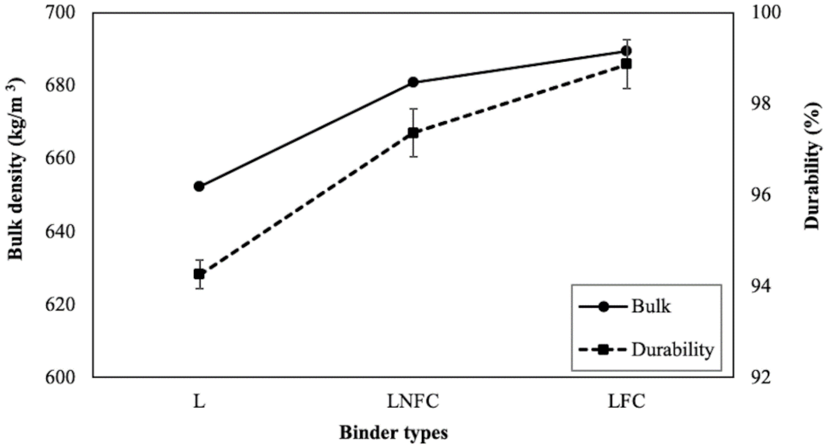

Figure 5 Effect of binding type on physical properties of pellets

3.5 Effect of mixing ratios on energy consumption in pellets production and mass yield

The effect of mixing ratios on energy consumption in pellets production and mass yield of pellets was presented in Figure 6. The mixing ratio with fermented cassava-rhizome as binder affected the energy consumption and mass yield. The results showed that the energy consumption in leucaena pellets production with the mixture 100:0, 90:10, 80:20, 70:30, 60:40, and 50:50 (leucaena: fermented cassava-rhizome) were 570 kWh/ton, 480 kWh/ton, 460 kWh/ton, 420 kWh/ton, 480 kWh/ton, and 500 kWh/ton, respectively. From the results obtained, the highest energy consumption for the pelletizing process was with the mixing ratio at 100:0 (leucaena: fermented cassava-rhizome), while the lowest energy consumption was with 70:30. The results indicated that a LFC case can decrease the energy consumption for the pellets production until the mixing ratio reaches 70:30. However, the energy consumption increased significantly by increasing the fermented cassava-rhizome content at a mixing ratio of 60:40 and 50:50 due to the increase of fermented cassava-rhizome content, which is due to increasing moisture content in the pelleting process. Moreover, the results of percentage of mass yield of pellets with mixing ratio at 100:0, 90:10, 80:20, 70:30, 60:40, and 50:50 were 86.5%, 87.6%, 91.6%, 94.3%, 91.5%, and 91.2%, respectively. It was observed that the mass yield of pellets gradually increased until the mixing ratio of 70:30 (leucaena: fermented cassava-rhizome), and after that it continuously decreased. For the commercial production, the important requirement for pellets production is low energy consumption and the high mass yield of pellets, as they decide the energy cost for pellets production. From the results, it was apparent that the mass yield of the pellets was the highest at the mixing ratio of 70:30. Thus, it can be concluded that the optimum mixing ratio for the production of leucaena pellet is 70:30. These results obtained from the analysis could provide guidelines for the energy consumption analysis of pellet production on a larger scale in the future.

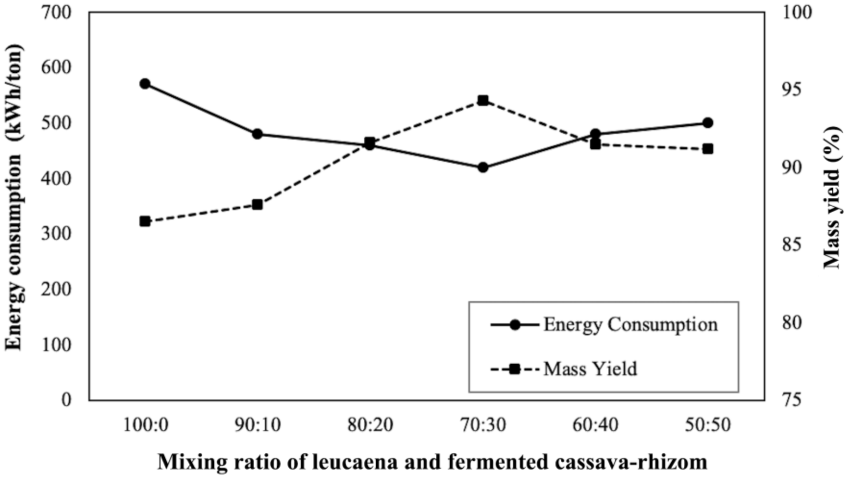

Figure 6 Effect of mixing ratios on energy consumption in pellets production and mass yield of pellets

4. CONCLUSION

This research concluded that the fermented cassava-rhizome affected the physical properties of leucaena pellets, which were determined according to the PFI standard. The increase in the mixing ratios with fermented cassava-rhizome content as binder effectively increased the bulk density and durability of leucaena pellets. Further, the physical properties (bulk density and durability) of LFC were of higher values than the LNFC and leucaena pellet without a binder. The mixing ratio affected the energy consumption during pellets production and mass yield of leucaena pellets. Moreover, it was found from the results that the optimum mixing ratio (leucaena: fermented cassava-rhizome) for the efficient production process of pellets was 70:30. This mixing ratio provided the lowest energy consumption 420 kWh/ton for pellets production and provided the highest mass yield of 94.3%. Thus, the results obtained from this research suggest that the fermented cassava-rhizome as the binder can be an alternative adhesive material for improving the asymmetrical structure and physical properties of biomass. Moreover, these results could provide guidelines for the energy consumption analysis for a larger scale of pellet production in the future. In future work, it should be considered together with its combustion behaviors and environmental friendliness.

REFERENCES

Ahn, B. J., Chang, H., Lee, S. M., Choi, D. H., Cho, S. T., Han, G., and Yang, I. (2014). Effect of binder on the durability of wood pellets fabricated from *Larix kaemferi* C. and *Liriodendron tulipifera* L. sawdust. *Renewable Energy*, 62,18-23.

Barz, M., and Delivand, M. K. (2011). Agricultural residues as promising biofuels for biomass power generation in Thailand. *Journal of Sustainable Bioenergy Systems*, 21-27.

Berghel, J., Frodeson, S., Granstrom, K., Renstrom, R., Stahl, M., Nordgren, D., and Tomani, P. (2013). The effects of kraft lignin additive on wood fuel pellet quality, energy use and shelf lift. *Fuel Processing Technology*, 112, 64-69.

Chotchutima, S., Kangvansaichol, K., Tudsri, S., and Sripichitt, P. (2013). Effect of spacing on growth, biomass yield and quality of leucaena (*Leucaena leucocephala* (Lam.) de Wit.) for renewable energy in Thailand. *Journal of Sustainable Bioenergy Systems*, 3(1), 48-56.

Garcia-Maraver, A., Rodriguez, M. L., Serrano-Bernardo, B., and Diaz, L. F., and Zamorano, M. (2015). Factors affecting the quality of pellet made from residual biomass of olive trees. *Fuel Processing Technology*, 129, 1-7.

Gil, M. V., Oulego, P., Casal, M. D., Pevida, C., Pis, J. J., and Rubiera, F. (2010). Mechanical durability and combustion characteristics of pellets. *Bioresource Technology*, 101(22), 8859-8867.

Hurun, N. Y., and Afzal, M. T. (2016). Effect of particle size on mechanical properties of pellets made from biomass blends. *Procedia Engineering*, 148, 93-99.

Intagun, W., and Tharawadee, N. (2016). The effect of particle size on the bulk density and durability of pellets: bagasse and eucalyptus bark. *Research and Knowledge*, 2(1), 74-79.

Intagun, W., Khamdaeng, T., Prom-ngarm, P., and Panyoyai, N. (2018). Effect of core puncture diameter on bio-char kiln efficiency. *International Journal of Biotechnology and Bioengineering*, 12(11), 435-439.

Izzati, R., Shaari, A. R., Mohammed, A. R., Khor, C. Y., Leng, L. Y., Jamalludin, M. R., and Makhtar, N. L. (2019). Determination of *Leucaena leucocephala* Sp pellet qualities under different percentage of cassava binders. *Journal of Advanced Research in Engineering Knowledge*, 7(1), 22-27.

Jiang, L., Yuan, X., Xiao, Z., Liang, J., Li, H., Cao, L., Wang, H., Chen, X., and Zeng, G. (2016). A comparative study of biomass pellet and biomass-sludge mixed pellet: Energy input and pellet properties. *Energy Conversion and Management*, 126, 509-515.

Kaliyan, N., and Morey, R. V. (2009). Factors affecting strength and durability of densified biomass products. *Biomass and Bioenergy*, 33(3), 337-359.

Kaliyan, N., and Morey, R. V. (2010). Natural binder and solid bridge type binding mechanisms in briquettes and pellets made from corn stover and switchgrass. *Bioresource Technology*, 101(3), 1082-1090.

Kanoksilapatham, W., Ogawa, M., and Intagun, W. (2020). Effect of clay and temperature on the slag formation of two biomass fuels: Wood from Acacia mangium and rhizome residual from *Manihot esculenta*. *Renewable Energy*, 156, 213-219.

Liu, Z., Liu, X., Fei, B., Jiang, Z., Cai, Z,. and Yu, Y. (2013). The properties of pellet from mixing bamboo and rice straw. *Renewable Energy*, 55, 1-5.

Liu, Z., Mi, B., Jiang, Z., Fei, B., and Cai, Z. (2016). Improved bulk density of bamboo pellets as biomass for energy. *Renewable Energy*, 86, 1-7.

Mani, S., Tabil, L. G., and Sokhansanj, S. (2006). Effects of compressive force, particle size, and moisture content on mechanical properties of biomass pellets from grasses. *Biomass and Bioenergy*, 30(7), 648- 654.

Martin, C., Wei, M., Xiong, S., and Jonsson, L. J. (2017). Enhancing saccharification of cassava stems by starch hydrolysis prior to pretreatment. *Industrial Crops and Products*, 97, 21-31.

Posom, J., Shreatha, A., Saechua, W., and Siricomboon, P. (2016). Rapid non-destructive evaluation of moisture content and higher heating value of

Leucaena leucocephala pellets using near infrared spectroscopy. *Energy*, 107, 464-472.

Prasertsan, S., and Sajjakulnukit, B. (2006). Biomass and biogas energy in Thailand: potential, opportunity and barriers. *Renewable Energy*, 31(5), 599-610.

Rattawan, K., Intagun, W., and Kanoksilapatham, W. (2019). Effect of coffee ground on physical and heating value properties of sugarcane bagasse pellets. *International Journal of Chemical and Materials Engineering*, 13(7), 377-380.

Singh, M. K., Kumar, M., and Thakur, I. S. (2017). Proteomic characterization and schizophyllan production by *Schizophyllum commune* ISTL04 cultured on *Leucaena leucocephala* wood under submerged fermentation. *Bioresource Technology*, 236, 29-36.

Warajanont, S., and Soponpongpipat, N. (2013). Effect of particle size and moisture content on cassava root pellet fuel's qualities follow the acceptance of pellet fuel standard. *International Journal of Sustainable and Green Energy***,** 2(2),74-79.

Wei, M., Zhu, W., Xie, G., Leatander, T. A., and Xiong, S. (2015). Cassava stem wastes as potential feedstock for fuel ethanol production: A basic parameter study. *Renewable Energy*, 83, 970-978.

Zhu, W., Lestandr, T. A., Orberg, H., Wei, M., Hedman, B., Ren, J., Xie, G., and Xiong, S. (2015). Cassava stems: A new resource to increase food and fuel production. *Global Change Biology Bioenergy*, 7(1), 72-83.