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An Experimental Investigation on the Handling and Storage Properties of Biomass Fuel Briquettes Made from Oil Palm Mill Residues

Chin Yee Sing and Mohd. Shiraz Aris
Department of Mechanical Engineering, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia

Abstract: This study is about experimental investigation on solid fuel briquettes made of oil palm mill residues that exhibit optimum handling and storage properties. One of the major technical challenges in utilizing biomass waste material as a solid fuel is the handling and storage issues of loose and wet waste material. The solid biomass fuel briquettes made from different types and combinations of palm oil mill residues were explored for optimum storage and handling features. A solution to improving the handling and storage properties of loosely-bound oil palm mill residues is proposed in this work via a densification process known as fuel briquetting. Raw oil palm waste material was pulverized and compacted with a 159 MPa pressing pressure to form 40 mm diameter solid fuel briquettes. It was found that a fuel briquette with a 60:40 palm kernel shell to mesocarp fiber ratio using waste paper as its binding agent gave the best mechanical properties without sacrificing the combustion properties of the solid fuel.

Key words: Briquette, palm kernel shell, palm fibre

INTRODUCTION

The thermal conversion of biomass waste material is the reverse process of photosynthesis, a process in which the plant produces food for itself. This two-way relationship is represented by the following equation:

$$CO_2 + 2H_2O \underset{heat}{\overset{light}{\rightleftharpoons}} CH_2O + H_2O + O_2$$

Whereas, use of biomass for energy is the reversal of photosynthesis. Oil palm waste material has been utilized extensively in energy recovery schemes for steam and power generation. It is one of the major renewable energy sources in use today especially in oil palm mills. The thermal conversion of palm oil biomass is considered carbon neutral (Mahadzir *et al*., 2010; Ahmad *et al*., 2011) due to the fact that the carbon dioxide emitted is balanced by the amount absorbed during the plants' growth. In Malaysia, the oil palm industry is a major contributor to the nation's economy as Malaysia is a major crude palm oil exporter, contributing 51% of the world's palm oil production in 2010 (Mohammed *et al.,* 2011; Nursulihatimarsyila *et al*., 2012). From the 421 oil palm mills operating in Malaysia in 2010, 4.46 million tonnes of Palm Kernel Shell (PKS), 7.73 million tonnes of mesocarp fibre or Palm Fibre (PF) and 21.34 million tones of Empty Fruit Bunches (EFB) were generated as the main mill residue components when the Fresh Fruit Bunches (FFB) are processed.

Since one of the major issues associated with burning biomass waste is its handling and storage (Baxter, 2005), densifying loosely-bound biomass material into briquettes can offer a solution which is much awaited by, not only the oil palm industry, but those involved in the utilization of solid fuels. This work investigated the handling and storage of biomass fuel briquettes made from oil palm mill residues through experiments for the various relevant mechanical properties.

MATERIALS AND METHODS

Energy content determination: The gross energy content or Higher Heating Value (HHV) was measured using a LECO bomb calorimeter. Oven dried samples of palm kernel shell (PKS), palm fiber (PF) and mixtures of PKS and PF were tested for their energy content.

The biomass briquetting process: The densification of biomass waste material from PKS and PF was carried out to produce solid fuel briquettes, similar to work of Yunardi *et al.* (2011). The as-received raw materials were dried in an oven to remove excess moisture. The dried samples were then pulverized and sieved into particle

Corresponding Author: Chin Yee Sing, Department of Mechanical Engineering, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia

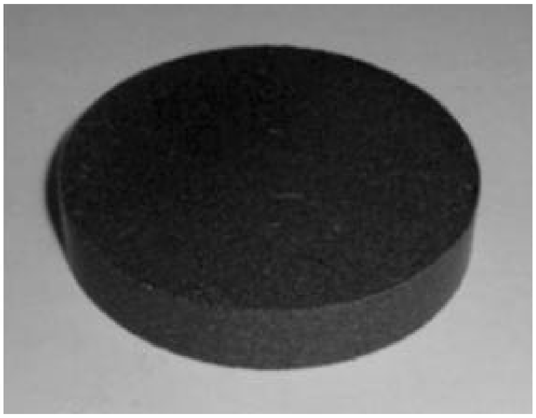

Fig. 1: A 10 g, 40 mm diameter palm oil mill residue solid fuel briquette

sizes of between 63 and 500 μm. The densification process used a 200 kN pressing load in a 40 mm-diameter steel die to form the end product as shown in Fig. 1.

A procedure to stabilize the inner tension affecting the microstructure and porosity of the briquettes, as suggested by Yaman *et al.* (2001) and Faizal *et al.* (2010), was adopted in this work to obtain stability and rigidity of the briquettes. To complete the procedure, the samples were left exposed under ambient conditions after their removal from the die set for a period of one week, following work of Yaman *et al.* (2000).

In order to measure good handling and storage properties, mechanical tests were carried out and their results were used to adjust the governing parameters such as pressing pressure and fuel component mixing ratios, following work of Chin *et al.* (2008).

Mechanical properties tests: The five types of mechanical properties tests carried out in this study include crack analysis, compressive strength, immersion, stability analysis and durability analysis. The results from these tests were important to analyze the handling, storage and transportation properties of fuel briquettes and were significant when the fuel briquettes need to be stored before transportation to the respective application sites. Previous work by Coates (2000) suggested that cost reduction for collection, handling, storage and transportation is most easily accomplished by densification. Faizal *et al.* (2010) emphasized the importance of mechanical strength and durability as factors towards producing high quality fuel briquettes.

As part of establishing mechanical strength, Husain *et al.* (2002) carried out crack analysis on fuel briquettes where the briquette samples were allowed to fall freely from a height of 1-2 m and the resulting crack length was measured. In this study, compressive strength tests were carried out with a 500 kN flexural and compression machine, where briquette samples were placed in between two flat, parallel plates and compressed by a vertical force until the briquettes fail. The compressive strength was calculated by having the load at fracture divided by the cross-sectional area of the plane of fracture, following the method by Yaman *et al.* (2000). Demirbas (1999) reported the results of tests on water resistance of the briquettes which were immersed in a container filled with cold tap water and the time required for dispersion in water was recorded.

In order to determine the stability of the briquettes, the briquettes' dimensions were taken immediately after removal from the die, after exposing to atmosphere for one week and again after exposing to atmosphere for five weeks, following the method adopted by Demirbas (1999). The durability test was carried out according to Al-Widyan *et al.* (2002) method, where the briquettes were dropped from a height of 1.85 m onto a flat steel plate for four times. The durability (%) was calculated as the ratio of final weight of material retained after four drops to the initial weight of the briquette, as shown in the following equation:

$$\text{Durability (\%)} = \frac{\text{Material weight in plate after 4 drops}}{\text{Initial weight of materials}} \times 100$$

Binding agent: Husain *et al.* (2002) explored the effects of powdered raw materials (PKS and PF) with water and starch as binders in fabricating briquettes. Other binder options in others' studies include used paper and newsprint. Demirbas's study found that kraft paper, newspaper and used paper waste could be used to bind together coal dust and other particulate combustible wastes to make a strong briquette (Demirbas, 1999). Research of Yaman *et al.* (2000) had found that the presence of paper mill waste increased the shatter index of the briquette obtained. Besides, sawdust and paper mill waste increased compressive strength of the briquettes, as discovered by Yaman *et al.* (2001).

RESULTS AND DISCUSSION

Mechanical properties of PKS and PF briquettes: From the energy content standpoint, unmixed PKS briquettes will give more promising results compared to unmixed PF briquettes. This is observed in the HHV results for unmixed PKS and PF. The unmixed PKS samples in this work recorded a 1.3 kJ g^{-1} higher HHV compared to the unmixed PF.

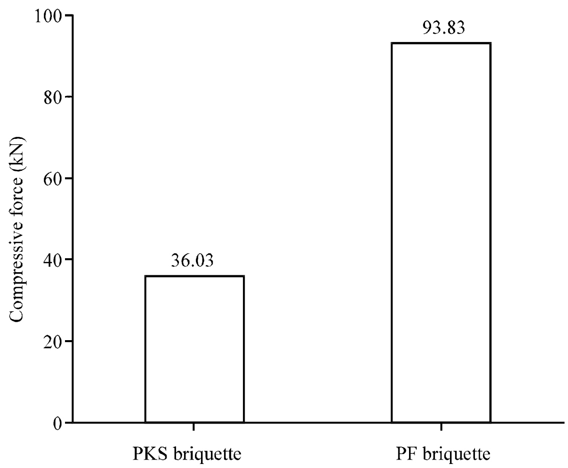

Fig. 2: Compressive strength test results of fuel briquettes

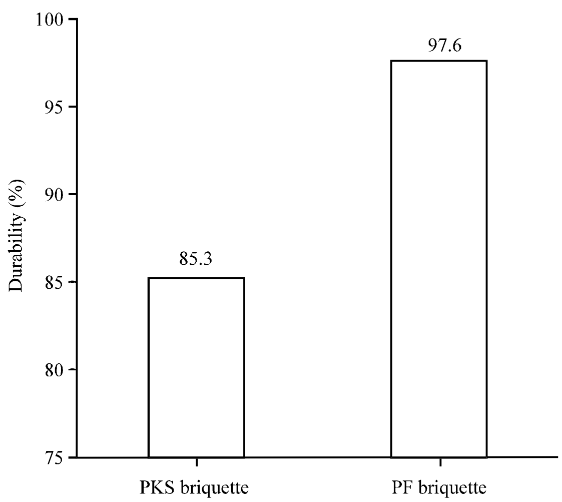

Fig. 3: Durability of fuel briquettes

In terms of their mechanical properties, briquettes made solely of PF were stronger than the PKS briquettes. In the crack test, the PKS briquettes consistently failed by shattering for all the five sample briquettes tested. In the compressive strength test, as shown in Fig. 2, PKS briquettes could only sustain a 36.03 kN force before failing whereas the PF briquettes could sustain a load up to 93.83 kN.

Water resistance of a solid fuel, measured in terms of time before disintegration, was observed to be better for the PF briquettes which recorded an extra 61 s resistance before failure compared to the PKS briquettes. As for stability, the PF briquettes expanded from 40 mm diameter to only 40.9 mm on average whereas the PKS briquettes expanded to 41.6 mm in the third week. The average

Table 1: Mixed-materials fuel briquettes*

60S:40F (p)	60S:40F (s)
50S:50F (p)	50S:50F (s)
40S:60F (p)	40S:60F (s)

S: Shell, F: Fiber, *All the numbers shown were in weight percent, p and s in parenthesis stand for paper and starch as binder, respectively

durability of PKS briquette was 85.3% compared to the 97.6% for PF briquette. The durability test results are shown in Fig. 3.

From the mechanical properties standpoint, PF briquettes were found to be superior to the PKS briquettes in the crack test, compressive strength test, water resistance test, stability analysis and durability test in this study. This was because the fibrous nature of PF tends to hold the fuel briquettes more firmly and thus, PF briquettes were more impact resistant, stronger to sustain higher compressive force, more water resistant, more stable in maintaining the dimension and more durable.

From both the energy content and mechanical properties standpoints, it can be observed from the results obtained that high quality fuel briquettes, which possess high calorific value and good mechanical properties, can be correlated to the mixing of PKS and PF materials. Apart from the mixing ratios, several literatures reported on the use of binder materials to further increase its mechanical strength. The addition of binding agents would, however, cause changes to both the mechanical property and energy content.

Following the work of Husain *et al.* (2002) on the addition of starch and water to powdered PKS and PF, and supplemented by the findings of Demirbas (1999) and Yaman *et al.* (2000), the mixing ratios of PKS and PF in this study were bound by paper and starch. The briquettes made from PKS, PF and a binder combination were analysed to get an optimum materials ratio that revealed characteristics of a good quality fuel briquette. The six combinations of biomass-binder mixture ratios that can be divided into the paper-binder group and starch-binder group studied in this work are shown in the Table 1.

High heating values and mechanical properties of mixed-materials briquettes: Generally, for mixtures from either paper-binder group or starch-binder group, the HHV for the 60S:40F mix was the highest compared to the 50S:50F and 40S:60F mix. This is due to the higher calorific value of PKS compared to PF. Considering the same PKS to PF ratio, the binding agent effect on HHV could be observed. For the 60S:40F, 50S:50F and 40S:60F mix, all the briquettes with paper binder were observed to have higher calorific values than their counterparts with starch binder. The comparison of HHV values for the same PKS-PF mix ratios but with different binding agent is shown in Fig. 4.

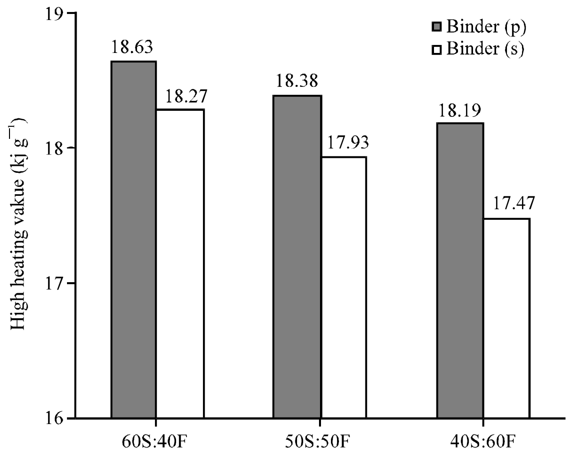

Fig. 4: Binder effect on high heating values of fuel briquettes, S: Shell, F: Fiber, p and s in parenthesis stand for paper and starch as binder, respectively

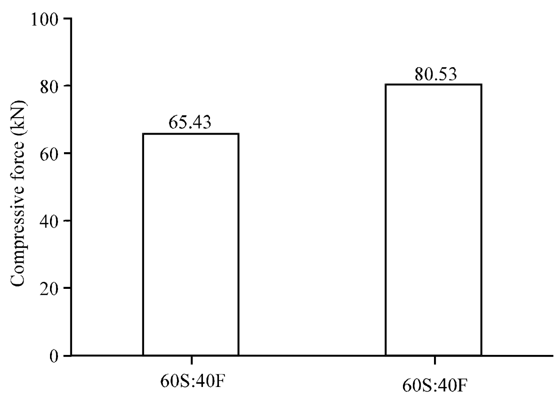

Fig. 5: Compressive strength test results of 60S:40F (s) and 60S:40F(p) Briquettes, S: Shell, F: Fiber, p and s in parenthesis stand for paper and starch as binder, respectively

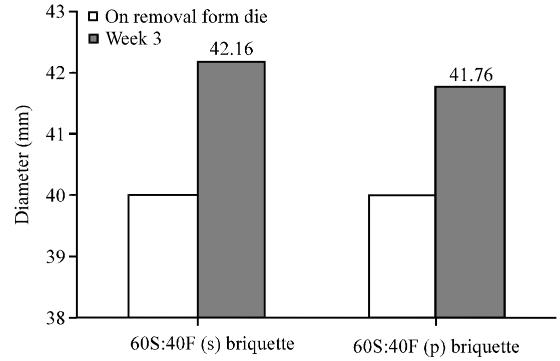

Fig. 6: Fuel briquettes diameters, S: Shell, F: Fiber, p and s in parenthesis stand for paper and starch as binder, respectively

Referring to the calorific value results, 60S:40F (p) briquette was a good choice since the calorific value was higher than other material ratios and all ratios using starch binder or without binder. The 60S:40F briquette had calorific value compatible to 60S:40F (p) briquette, therefore, whether or not a binder was needed was further investigated and justified by the results from mechanical properties tests. The five mechanical properties tests were done and compared between the two briquettes - 60S:40F (p) and 60S:40F briquettes.

The crack test was the most straight forward test to check if the fuel briquette had good handling properties. It was observed that the cracks on the 60S:40F and the unmixed PKS briquettes were similar in severity. The briquettes which used paper as their binding agent was found to have withstood the crack test. Therefore, it was obvious that paper binder was necessary to ensure good handling properties of a fuel briquette.

Referring to Fig. 5, comparing the maximum load before failure sustained by the two briquettes, the 60S:40F (p) briquette showed higher load resistance than 60S:40F briquette. The 80.53 kN load sustained by 60S:40F (p) briquette was a lot more than the 65.43 kN sustained by 60S:40F briquette. As discovered by Yaman *et al.* (2001) presence of fibrous paper increased compressive strength of the briquettes.

However, the 60S:40F briquette was a bit more water resistant than 60S:40F (p) briquette. The 60S:40F briquette took 9.99 sec more to fully-dispersed in water, so it was slightly more water resistant than 60S:40F (p) briquette. The paper content in the 60S:40F (p) was a rather water-sensitive binder that promoted water absorption of the fuel briquette, thus resulted in a lower water resistance ability of 60S:40F (p) briquette.

The 60S:40F (p) briquette managed to preserve its diameter better than the 60S:40F briquette. This showed that a binder played a crucial part in maintaining the dimension of a fuel briquette, which was important during storage. On the third week after briquetting, the diameter of 60S:40F (p) briquette expanded only 1.76 mm but the 60S:40F briquette expanded 2.16 mm. The results are illustrated in Fig. 6.

When the durability of the fuel briquettes was compared, the one with paper binder was more durable than the one without paper binder. 60S:40F (p) briquette had durability value of 98.7% whereas 60S:40F briquette showed only 98.1%. Similar to Demirbas's research, using paper in briquette would make the briquette stronger (Demirbas, 1999).

CONCLUSION

A 10 g solid biomass fuel briquette using palm oil mill residues with good handling and storage properties was identified to be the 60S:40F (p) briquette. This is an early indication that the developed fuel briquettes are able to withstand the harsh handling environment which is typically found in power plants.

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REFERENCES

Ahmad, M.M., M.F. Aziz, A. Inayat and S. Yusup, 2011. Heat integration study on biomass gasification plant for hydrogen production. J. Applied Sci., 11: 3600-3606.

Al-Widyan, M.I., H.F. Al-Jalil, M.M. Abu-Zreig and N.H. Abu-Hamdeh, 2002. Physical durability and stability of olive cake briquettes. Can. Biosyst. Eng., 44: 41-45.

Baxter, L., 2005. Biomass-coal co-combustion: Opportunity for affordable renewable energy. Fuel, 84: 1295-1302.

Chin, Y.S., H.H. Al-Kayiem, C. Rangkuti, M.S. Aris and S. Hassan, 2008. Experimental investigations on fuel briquettes produced from agricultural and industrial waste. Proceedings of the 1st ICPER International Conference on Plant Equipment and Reliability, March 27-28, 2008, Selangor, pp: 52-57.

Coates, W., 2000. Using cotton plant residue to produce briquettes. Biomass Bioenergy, 18: 201-208.

Demirbas, A., 1999. Physical properties of briquettes from waste paper and wheat straw mixtures. Energy Convers. Manage., 40: 437-445.

Faizal, H.M., Z.A. Latiff, M.A. Wahid and A.N. Darus, 2010. Physical and Combustion Characteristics of Biomass Residues from Palm Oil Mills. In: New Aspects of Fluid Mechanics, Heat Transfer and Environment, Mastorakis, N.E., V. Mladenov and Z. Bojkovic (Eds.). Wiley, New York, USA., ISBN: 978 -960-474-215-8, pp: 34-38.

Husain, Z., Z. Zainac and Z. Abdullah, 2002. Briquetting of palm fibre and shell from the processing of palm nuts to palm oil. Biomass Bioenergy, 22: 505-509.

Mahadzir, M.M., Z.A. Zainal, M. Iqbal and S.N. Soid, 2010. Characteristics on fluidization behaviors of 1000 μm CaO-sand mixture by varying the percentage of CaO, air flow rate and pressure. J. Applied Sci., 10: 745-751.

Mohammed, M.A.A., A. Salmiaton, W.A.K.G. Wan Azlina and M.S.M. Amran, 2011. Gasification of empty fruit bunch for hydrogen rich fuel gas production. J. Applied Sci., 11: 2416-2420.

Nursulihatimarsyila, A.W., L.L.N. Harrison and Y.M. Choo, 2012. Value-added products from palm sludge oil. J. Appl. Sci., 12: 1199-1202.

Yaman, S., M. Sahan, H. Haykiri-Acma, K. Sesen and S. Kucukbayrak, 2000. Production of fuel briquettes from olive refuse and paper mill waste. Fuel Process. Technol., 68: 23-31.

Yaman, S., M. Sahna, H. Haykiri-Acma, K. Sesen and S. Kucukbayrak, 2001. Fuel briquettes from biomass-lignite blends. Fuel Process. Technol., 72: 1-8.

Yunardi, Zulkifli and Masrianto, 2011. Response surface methodology approach to optimizing process variables for the densification of rice straw as a rural alternative solid fuel. J. Applied Sci., 11: 1192-1198.