EFFECTS OF EMPTY FRUIT BUNCH STORAGE DURATION ON MOISTURE CONTENT AND HIGHER HEATING VALUE

MUHAMAD AFIQ BIN ABDUL RASHID

A dissertation submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering

School of Chemical and Energy Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JANUARY 2020

ABSTRACT

Empty fruit bunch (EFB) is part of the waste produced in the manufacturing of palm oil products. EFB is regarded to have the lowest economic value compared to palm kernel shell (PKS) and mesocarp fibre (MF) as it contains high amount of moisture. When dried to remove moisture, EFB quality and economic value can be increased. However, there is a lack of study that predicts the Higher Heating Value (HHV) of EFB based on the moisture content. This study aims to develop the correlation between the moisture content to the HHV and revenue generated by selling steam in order to clarify the problem. This study also aims to find the effects of storage duration on quality of EFB. The samples collected were divided into two stages; Stage 1 to study effects of moisture content on HHV while Stage 2 to study the effects of storage duration on moisture content and HHV. For Stage 2, 60g to 100g was taken from each sample daily to measure the moisture content and HHV. The result of this study is a linear correlation of the HHV and moisture content, y=-14.343x+17.601 with coefficient of determination, R^2 value of 0.9858. It indicates a good fit linear regression. This correlation is useful in estimating the HHV of the EFB at known moisture content and to calculate the amount of steam and revenue that can be generated. The study of the storage duration effect shows the HHV increased when EFB is stored during the 7-day period. A financial mechanism in terms of price reduction was proposed based on the quality of EFB when used as fuel for boiler to produce a one tonne of steam. The EFB quality was categorised as High if moisture content less than 13 % and Low if the moisture content greater than 37 %. If the moisture content in between is regarded as medium quality. The proposed financial mechanism considered profit or losses and price reduction was suggested for lower quality of EFB according to the loss incurred. This financial mechanism can also be used in the related industry to standardise their EFB feedstock, predict the output of steam and revenue generated from selling steam, and estimate the price of EFB per tonne of steam according to the quality of EFB supplied.

ABSTRAK

Tandan buah kosong (TBK) merupakan bahan sampingan yang terhasil daripada proses pembuatan produk kelapa sawit. TBK dianggap mempunyai nilai ekonomi yang paling rendah dibandingkan dengan tempurung kelapa sawit (TKS) dan serat mesokarp sawit (SMS) kerana mempunyai kandungan lembapan yang tinggi. Apabila dirawat untuk membuang kandungan lembapan, kualiti dan nilai ekonomi TBK boleh ditingkatkan. Walaubagaimanapun, terdapat sedikit sahaja kajian yang pernah dijalankan mengenai korelasi kandungan tenaga TBK berdasarkan kandungan lembapan. Kajian ini dijalankan untuk membuat perhubungan antara kandungan lembapan dengan kandungan tenaga dan jumlah stim yang dihasilkan. Kajian ini juga dijalankan untuk memahami kesan tempoh simpanan jangka masa pendek terhadap kualiti TBK. Sampel yang diambil telah dibahagi kepada dua bahagian; Bahagian 1 digunakan untuk mengkaji kesan kandungan lembapan terhadap kandungan tenaga manakala Bahagian 2 digunakan untuk mengkaji kesan simpnana terhadap kandungan lembapan dan kandungan tenaga. 60g hingga 100g diambil daripada sampel Bahagian 2 setiap untuk mengukur kandungan lembapan dan kandungan tenaga. Hasil kajian ini mendapati korelasi antara kandungan tenaga dan kandungan lembapan TBK ialah linear, $y=-14.343x+17.601$ dan nilai korelasi penentuan, R^2 ialah 0.9858. Korelasi ini menunjukkan perkadaran langsung yang baik. Korelasi ini boleh digunakan untuk menentukan kandungan tenaga TBK berdasarkan kandungan lembapan dan untuk menganggarkan jumlah stim yang boleh dihasilkan. Kajian terhadap kesan tempoh simpanan TBK mendapati kandungan tenaga TBK lebih tinggi jika disimpan dalam jangka masa pendek. Satu mekanisma kewangan telah dicadangkan berdasarkan kualiti TBK yang digunakan sebagai bahan bakar untuk dandang yang menghasilkan 1 tan stim. Kualiti TBK diklasifikasikan sebagai Tinggi jika kandungan lembapan kurang daripada 13 % dan Rendah jika kandungan lembapan melebihi 37 %. Cadangan mekanisma kewangan ini mengambil kira untung rugi dan pengurangan harga dicadangkan untuk TBK kualiti rendah. Mekanisma kewangan ini boleh digunakan dalam industri yang berkaitan untuk menyeragamkan kualiti TBK yang digunakan selain menganggarkan pengeluaran stim dan keuntungan yang diperoleh daripada penjualan stim. Mekanisma ini juga boleh digunakan untuk mengira harga TBK yang perlu dibayar berdasarkan kualiti TBK.

`

TABLE OF CONTENTS

`

LIST OF TABLES

`

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysia is one of the world's biggest palm oil producers, only behind to Indonesia. The export of palm oil has helped to change Malaysia's economy and agriculture landscape. In 2016, Malaysia produced 19 MT of crude palm oil while in 2017, the production increased by 8% to 20.5 MT (Malaysian Palm Oil Board, 2017). In 2016, Malaysia's palm oil production made up 29 % of world's palm oil production (Varga 2017). World palm oil production has grown rapidly in the global market since the past four decades. On the global scale, the total palm oil production has more than doubled in 1990 to 11 MT from 5 MT in 1980. By the turn of the century, the production has significantly increased to 21.8 MT (Abdullah & Sulaiman, 2013).

Palm fruit is harvested from oil palm tree that produces two main products, crude palm oil (CPO) and palm kernel oil (PKO) (Aziz, et al., 2014). These two products are different in terms of the compositions of saturated and unsaturated fats. In 2017, Malaysia produced more than 11 MT of CPO and 1.2 MT of PKO (Malaysian Palm Oil Board, 2017).

On the other hand, palm oil biomass which contains lignocellulose includes oil palm trunks (OPT), oil palm fronds (OPF), empty fruit bunch (EFB), palm pressed fibres (PPF) and palm shells (Abdullah & Sulaiman, 2013). Statistically, the useful

products obtained from palm trees which consist of CPO and PKO, are made up of only 10 % of the raw materials (Aziz et al., 2014). The rest of the biomass are not as useful and previously often discarded as waste. The presence of these waste creates a major disposal issue and pollution problems that all palm oil producers faced.

Palm oil manufacturing processes generate huge amount of solid waste and wastewater that if released into the environment would cause major pollution issues. The solid wastes are made up of EFB, mesocarp fruit fibres (MF) and palm kernel shells (PKS) (Abdullah & Sulaiman, 2013). These solid wastes have a lot potential to be utilised more efficiently in downstream processes. To combat the disposal and pollution issues, the wastes are used in other applications such as fuel for energy generation, development of bio-fuel and making of paper pulp. Another alternative usage of these waste is to be used as source of renewable energy to reduce the dependency on the fossil fuel.

EFB are lignocellulosic residues from palm oil trees which can be used in paper making due to its high number of fibres per unit weight (Abdullah & Sulaiman, 2013). EFB can also be made into medium density fibre-boards (MDF). However, these options are currently not seen as potential profitable new products and most operators of palm oil mills and cogeneration plants are more interested in using EFB as fuel similar to PKS and MF. In Nigeria, EFB has also been transported back to plantations to be used as mulching agent to enhance water retention and organic matter in the soil (Salako et al., 2014). However, Salako et al., (2014) also stated that the economic value of EFB for power generation is 3.5 times than mulching in plantations. In Malaysia, most palm oil producers either used the solid waste to generate energy for their own usage or sent to plants that use solid waste as fuel to produce their own final products.

The energy demand in Malaysia has shown to be increasing steadily from 1980 until 2010. In 2020, the energy demand is expected to increase to 73.6 Mtoe (million tonnes of oil equivalent) and is set to reach 100 Mtoe by 2030. Development of

renewable energy source in Malaysia is growing rapidly (Begum & M Saad, 2013). As of 2009, renewable energy only made up 5.5 % of total energy supply according to Shafie et al., (2011) and has increased to 22.5 % in 2017 (Bernama, 2017).

In order to increase the renewable energy production in Malaysia and to reduce pollution from open burning, palm oil waste including EFB are used as fuel in many plants in Malaysia. However, most palm oil producers and plant operators face the issue of inconsistent quality of EFB which depends heavily on the moisture content. EFB with high moisture content is not desirable as the moisture reduces the efficiency of combustion significantly.

Besides that, most plants also do not have proper storage planning of the fuel feedstock. The feedstocks are usually stored in a semi-enclosed building with roof with one main entrance and one side entrance door for access of supply lorries and machineries. The feedstocks storage typically does not have proper ventilation system to assist in natural drying process. The different type of feedstocks are placed side by side against the wall of the building and are often stacked up. Stacking up of the feedstock may cause older feedstock or wet feedstock to be buried underneath newer feedstock. This may prevent wet feedstock buried underneath from drying naturally. The buried feedstock may also be stored for a longer period than supposed to due to the arrangement of the feedstock that did not follow the first in, first out rule. The first in, first out procedure would ensure older feedstock are used up before using the newer supply. The rule would also ensure the feedstock are dried to low enough level of moisture to improve the HHV value.

1.2 Problem Statement

EFB is a biodegradable, non-hazardous material that is considered as waste after oil palm fruits extraction. It is produced during threshing of fresh fruit bunch (FFB) to remove palm fruit from FFB (Aziz et al., 2014). PKS and MF are widely used in the development of renewable and green energy sources due to their superior economic value. Their economic values are higher due to lower moisture content which naturally provide higher sensible energy when combusted.

Thermal and electrical energy in palm oil mills are usually generated using power generators that incorporates steam boilers. EFB, naturally, has very high moisture content and regarded to have the lowest economic value compared to PKS and MF. The moisture content of EFB is usually between 50 wt% to 60 wt% and can be up to 70 wt% (Ho et al.,2013). When used as fuel, a high fraction of the energy will be used to heat up moisture embedded within the EFB. As a result of this, the sensible energy of the biomass is reduced significantly. This is due to the high latent heat of vaporisation of water.

Raw EFB may be left out in storage spaces for a few days as palm oil mills does not usually receive consistent supply on daily basis. Palm oil mills may receive high amount of EFB on one day and may not receive any new feedstock the next day. Palm oil mills also typically receive EFB supply from different suppliers. This causes inconsistent quality of EFB being fed into the boilers which may result in inconsistent amount and quality of final products. This problem is become worse if there is no proper storage planning and ventilation.

While the moisture content is expected to decrease during storage, the quality in terms of HHV may increase for the first few days and drop thereafter. The improvement in quality may be primarily due to the loss of moisture. However, fungi and bacteria are naturally present within EFB and thrive with the presence of moisture

and air which could decrease the carbon content of EFB. The decrease in carbon could result in the decrease of HHV.

1.3 Objectives

From the problem statements above, the objectives of the research are defined as follows:

1. To correlate the moisture content of EFB and its energy content
2. To study the effects of storage duration on the energy content
3. To propose a financial mechanism based on the EFB quality

1.4 Research Scope

The EFB samples was collected from storage of Bio-Xcell Sdn. Bhd. and the experiment were carried out at Laboratory, UTM. The moisture content of EFB was determined by using oven drying method in air at 105 ºC where most of the sample were partially dried and the rest are dried until a constant weight is obtained for completely dried sample. Combustion in bomb calorimeter method was carried out to measure the calorific value of EFB. The correlation for HHV and moisture content was deduced using curve-fitting regression method.

The second objective focussed on the effect of short-term storage duration of EFB. The effects were determined by examining the heating value under two storage conditions, indoor and outdoor storage. The experiment was conducted for seven (7)

days with one-day intervals. The correlation for HHV and moisture content were also deduced using curve-fitting regression method.

The financial mechanism was proposed as operating procedure for plants or palm oil mills that use EFB as fuel. The mechanism includes the expected profit or loss when selling steam as product at different quality of EFB. The quality of EFB is divided into high, medium and low based on the projected revenue. Lower quality EFB may significantly reduce the profit and thus a penalty can be imposed on suppliers that supply low quality EFB.

`

REFERENCES

Abas, R., Kamaruddin, M.F., Nordin, A.B.A. and Simeh, M., 2011. A study on the Malaysian oil palm biomass sector—supply and perception of palm oil millers. Oil Palm Industry Economic Journal, 11(1), pp.28-41.

Abdullah, N. & Sulaiman, F., 2013. The Oil Palm Wastes in Malaysia. In: M. D. Matovic, ed. Biomass Now: Sustainable Growth and Use. Penang: Intech, pp. 75-100.

Aghamohammadi, N., Reginald, S., Shamiri, A., Zinatizadeh, A., Wong, L. and Nik Sulaiman, N., 2016. An investigation of sustainable power generation from oil palm biomass: a case study in Sarawak. Sustainability, 8(5), p.416.

Aljuboori, A. H. R., 2013. Oil Palm Biomass Residue in Malaysia: Availability and Sustainability. International Journal of Biomass and Renewables, pp. 13-18.

Atnaw, S.M., Sulaiman, S.A., Singh, L., Wahid, Z.A., Che, C.K.M.F.B. and Yahya, K., 2017. Modeling and parametric study for maximizing heating value of gasification syngas. BioResources, 12(2), pp.2548-2564.

Atnaw, S. M., Sulaiman, S. A. & Yusup, S., 2014. Influence of Fuel Moisture Content and Reactor Temperature on the Calorific Value of Syngas Resulted from Gasificaion of Oil Palm Fronds. The Scientific World Journal, Volume 2014, pp. 1-9.

Aziz, M., Oda, T. & Kashiwagi, T., 2014. Innovative Steam Drying of Empty Fruit Bunch with High Energy Efficiency. Drying Technology, 33(4), pp. 395-405.

Aziz, M., Oda, T., Kashiwagi & Takao, 2015. Innovative Steam Drying of Empty Fruit Bunch with High Energy Efficiency. Drying Technology, 33(1), pp. 395-405.

Aziz, M., Prawisudha, P., Prabowo, B. & Arief Budiman, B., 2015. Integration of Energy-Efficient Empty Fruit Bunch Drying with Gasification/Combined Cycle Systems. Applied Energy, 139(1), pp. 188-195.

Begum, S. & M Saad, M. F., 2013. Techno-economic Analysis of Electricity Generation from Biogas Using Palm Oil Waste. Asian Journal of Scietific Research, 6(2), pp. 290-298.

Bernama, 2017. KeTTHA eyes 30% renewable energy generation in eight years, Banting: The Star.

California State University, Northridge, 2010. Experiment 1: Adiabatic Bomb Calorimeter, Los Angeles: California State University, Northridge.

Che Khalib, N., Abdullah, N. & Sulaiman, F., 2009. Drying Pre-treatment on Empty Fruit Whole Bunches of Oil Palm Wastes. Melaka, American Institute of Physics.

Demirbas, A., 2002. Relationships between Heating Value and Lignin, Moisture, Ash and Extractive Contents of Biomass Fuels. Energy Exploration & Exploitation, 20(1), 105–111.

Dickerson, T. & Soria, J., 2013. Catalytic Fast Pyrolysis: Review. Energies, 6(1), pp. 514-538.

Elneel, R., Sulaiman, S. A. & Ariwahjoedi, B., 2013. Prediction of Heating Values of Fermoso, J., Pizarro, P., Coronado, J. M. & Serrano, D. P., 2017. Advanced Biofuels Production by Upgrading of Pyrolysis Bio-Oil. WIREs Energy and Environment, 6(4).

Graham, S., Eastwick, C., Snape, C. & Quick, W., 2017. Mechanical Degradation of Biomass Wood Pellets during Long Term Stockpile Storage. Fuel Processing Technology, 160(1), pp. 143-151.

Graham, S. L., 2015. Degradation of Biomass Fuels during Long Term Storage in Indoor and Outdoor Environments. Nottingham: University of Nottingham.

Hamada Boiler Web Catalogue, 2008, [Online] Available at: http://www.hamadaboiler.com/catalogue/page-5-steam-cost-all-countries.html. [Accessed 27.08.2019].

Han, J., & Kim, J., 2018. Process Simulation and Optimization of 10-MW EFB Power Plant, 43, pp. 723-729.

Hashim, N. A. Rosmin, N., Musta'amal, A.H., Ishak, B., & Barton, J. P., 2017. Syngas Performance of Biomass Gasification Using Palm Oil Fronds. International Journal of Power Energy Research, 1(2), pp. 93-102.

Heidenreich, S., Muller, M., & Foscolo, P. U., 2016. Biomass Pretreatment, in S Heidenreich, M Muller., & P U Foscolo (eds), Advanced Biomass Gasification: New Concepts for Efficiency Increase and Product Flexibility, Academic Press, pp. 11-17.

Hon, J. L. M., 2010. A Case Study on Palm Empty Fruit Bunch as Energy Feedstock. SEGi Rev, 3(2), pp. 3-15.

Ho, T. L., Tsz, Y. G. L., Oyedun, A. O. & Gebreegziabher, T., 2013. Drying of Biomass for Power Generation: A Case Study on Power Generation from Empty Fruit Bunch. Energy, 63(1), pp. 205-215.

Kumar, H., Baredar, P., Agrawal, P. & Soni, S. C., 2014. Effect of Moisture Content on Gasification Efficiency in Down Draft Gasifier. International Journal of Scientific Engineering and Technology, 3(4), pp. 411-413.

Lee, J.S., Sokhansanj, S., Lau, A.K., Lim, C.J., Bi, X.T., Basset, V., Yazdanpanah, F. and Melin, S., 2015. The effects of storage on the net calorific value of wood pellets. Canadian Biosystems Engineering, 57(1). pp. 85-92.

Lim, C. H., Salleh, E., & Jones, P., 2006. Renewable Energy Policy and Initiatives in Malaysia. International Journal on Sustainable Tropical Design Research & Practice, 1(1), pp. 33-40.

Malaysian Innovative Agency, 2012. National Biomass Strategy 2020. [Online] Available at: https://www.nbs2020.gov.my/key-principles [Accessed 30 12 2019]

Malaysian Palm Oil Board, 2017. Malaysian Palm Oil Board. [Online] Available at: http://bepi.mpob.gov.my/index.php/en/statistics/production/177-production-2017/798-production-trend-2017.html [Accessed 1 3 2018].

Norfadhilah Hamzah, Tokimatsu, K., & Yoshikawa, K., 2019. Solid Fuel from Oil Palm Biomass Residues and Municipal Solid Waste by Hydrothermal Treatment for Electrical Power Generation in Malaysia: A Review. Sustainability, 11. doi:10.3390/su11041060

Novianti, S., Biddinika, M. K., Prawisudha, P. & Yoshikawa, K., 2014. Upgrading of Palm Oil Empty Fruit Bunch Employing Hydrothermal Treatment in Lab-Scale and Pilot Scale. Procedia Environmental Sciences, 20(1), pp. 46-54.

Nurhidayati, & Leon, K. M., 2012. Malaysia's Biomass Potential. BESustainable. [Online] Available at: http://www.besustainablemagazine.com/cms2/malaysias-biomass-potential/ [Accessed 30 12 2019]

Nyakuma, B. B., Johari, A., Ahmad, A. & Tuan Abdullah, T. A., 2014. Comparative Analysis of the Calorific Fuel Properties of Empty Fruit Bunch and Briquette. Energy Procedia, 52(1), pp. 466-473.

Oktaviananda, C., Rahmawati, R.F., Prasetya, A., Purnomo, C.W., Yuliansyah, A.T. and Cahyono, R.B., 2017, March. Effect of temperature and biomass-water

ratio to yield and product characteristics of hydrothermal treatment of biomass. In AIP Conference Proceedings (Vol. 1823, No. 1, p. 020029). AIP Publishing.

Olisa, Y. P. & Kotingo, K. W., 2014. Utilisation of Palm Empty Fruit Bunch (PEFB) as Solid Fuel for Steam Boiler. European Journal of Engineering and Technology, 2(2), pp. 1-7.

Onoja, E., Chandren, S., Abdul Razak, F. I., Mahat, N. A., Abdul Wahab, R., 2018, March. Oil Palm (Elaeis guineensis) Biomass in Malaysia: The Present and Future Prospects. Springer

Ozyuguran, A. & Yaman, S., 2017. Prediction of Calorific Value of Biomass from Proximate Analysis. Energy Procedia, 107(1), pp. 130-136.

Robb, S., Dargusch, P., 2014. A financial analysis and life-cycle carbon emission assessment of oil palm waste biochar exports from Indonesia for use in Australian broad-acre agriculture. Carbon Mangement, 9(2), pp. 105-114.

Salako, Y. A., Owolarafe, O. K. & Anozie, A. N., 2014. Performance Evaluation of a Small Scale Palm Fruit Biomass-Fired Boiler. International Agricultural Engineering , 16(4), pp. 51-56.

Saletes, S., Caliman, J. P., Raham, D., 2014. Study of Mineral Nutrient Loss from Oil Palm Empty Fruit Bunches during Temporary Storage. Journal of Oil Palm Research, 16(1), pp. 11-21.

Shafie, S. M., Mahlia, T. M., Masjuki, H. H. & Andriyana, A., 2011. Current Energy Usage and Sustainable Energy in Malaysia: A Review. Renewable & Sustainable Energy Reviews, 15(9).

Shamsuddin, A. H., 2015. Boosting Malaysian renewable energy, Kuala Lumpur: Energy World.

Shariff, A., Mohamad Aziz, N. S. & Abdullah, N., 2014. Slow Pyrolysis of Oil Palm Empty Fruit Bunches for Biochar Production and Characterisation. Journal of Physical Science, 25(2), pp. 97-112.

Shuit, S. H., Tan, K. T., Lee, K. T. & Kamaruddin, A. H., 2009. Oil Palm Biomass as a Sustainable Energy Source: A Malaysian Case Study. Energy, 34(1), pp. 1225-1235.

Sulaiman, F., Abdullah, N. & Aliasak, Z., 2013. Solar Drying System for Drying Empty Fruit Bunch. Journal of Physical Science, 24(1), pp. 75-93.

Uemura, Y., Trinh, T. H., Samsuddin, M. & Omar, W., 2017. The Effect of Natural

Degradation on the Properties of Three Types of Oil Palm Residue. International Journal of Biomass & Renewables, 6(2), pp. 11-22.

Varga, S., 2017. Essential Palm Oil Statistics 2017, Singapore: Palm Oil Analytics.

Wong, S. L., Ngadi, N., Tuan Abdullah, T. A. & Inuwa, I. M., 2015. Recent advances of feed-in tariff in Malaysia. Renewable and Sustainable Energy Reviews, 41(1), pp. 42-52.

Zafar, S., 2019. Energy Potential of Empty Fruit Bunch. BioEnergy Consult. [Online] Available at: https://www.bioenergyconsult.com/bioenergy-potential-empty-fruit-bunches/