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Development of Palm Oil Extraction Performance Index (EPI) Based on Oil Extraction Rate (OER) and Oil Loss (OL)

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ABSTRACT

This study proposes a new method to evaluate the performance of palm oil extraction based on Predictive Scoring Index methodology. The variables, Oil Extraction Rate (OER) and Oil Loss (OL), were identified as important to develop a new extraction index based on three different steriliser systems. There were six performance categories: Excellent, Very Good, Good, Average, Poor and Very Poor. Based on 75 selected palm oil mills data from 2009-2013, Continuous Sterilizer (CS) system and Conventional Sterilizer (CV) system recorded 2.7% and 1.3% respectively under the Excellent category. The Compact Modular Concept (CMC) system only recorded 'Very Good' (20%) and 'Good' (13.3%). This study showed that EPI could be used to monitor palm oil extraction performance to ensure maximum oil extraction and minimum losses.

Keywords: Extraction performance index, oil extraction rate, oil loss, palm oil mill

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INTRODUCTION

Currently, oil extraction rate (OER) is the only method used to assess the palm oil mill performance (Oberthur, 2014). At the management level, it is used to indicate the profitability of the plantation in order to measure the amount of oil extracted per hectare (Chang et al., 2003). The OER is defined as the percentage of oil recovered from the oil palm fresh fruit bunches (FFB) processed in the mill. Previous studies showed

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that there were several factors affecting OER such as rainfall, crop variety, ergonomic practices and cage weight (Salmiyati et al., 2014; Vincent et al., 2014; Sambanthamurthi et al., 2009). At present, there is no study conducted to understand the effects of using different steriliser systems on OER and oil loss (OL). The standard types of sterilisation system widely employed in Malaysia are continuous steriliser (CS), conventional steriliser (CV) and compact modular concept (CMC) (Hadi et al., 2014; Sivasothy et al., 2006; Sivasothy et al., 2005). Nowadays, sustainability in the palm oil industry, especially in the aspect of environmental management, is a major concern for better biomass waste management (Choong & McKay, 2013; Umar et al., 2013). The largest palm biomass material produced at the mill are oil palm empty fruit bunches (EFB) (Baharuddin et al., 2013), palm oil mill effluent (POME) (Sulaiman et al., 2010; Rupani et al., 2010), oil palm mesocarp fibre (MF) (Nordin et al., 2013) and oil palm decanter cake (OPDC) (Adam et al., 2014; Sahad et al., 2014). Abdullah and Sulaiman (2013) reported the presence of oil in palm biomass means it had a good potential to be recovered for various utilisation. The percentage of Oil Loss (OL) contained in palm biomass are between 0.25% and 1.38% dry EFB (Md. Yunos et al., 2015), 5% - 11% MF (Subramaniam et al., 2013; Nik Norulaini et al., 2008), 0.6% - 0.7% POME (Wan Sharifudin et al., 2015), and 12% OPDC (Sahad, 2015). Oil loss refers to the amount of crude palm oil absorbed in the palm biomass produced in the palm oil mill. An efficient palm oil milling process produces high OER whilst maintaining low OL. The OL is produced due to equipment inefficiency in extracting the maximum crude palm oil during the milling process and therefore the oil is absorbed in the palm biomass generated. Thus, high OL will reduce the palm oil extraction performance of the mill.

Nevertheless, the current extraction performance tool should be updated with the addition of a new factor in the consideration of sustainability issues in palm oil production (Cock et al., 2014). The objective of this study is to develop a new extraction performance index (EPI) with OER and OL as main variables due to their dependent relationship affecting the oil extraction performance (Juliano et al., 2013; Lin, 2011). This empirical study is unique as it analyses OL and the variables of existing palm oil mill production. The straightforward of OER and OL approach in EPI assist the performance assessment. Hence, the relationship between the variables and new EPI were studied for better understanding of their role in oil extraction performance.

METHOD

The approach in correlating the variables and new index through Predictive Scoring Index methodology was done in three steps; in the first step, the OER was calculated to represent the effectiveness of mill production. In the second step, the components involved in OL were identified and calculated to represent their effectiveness in palm oil production. The last step was to examine the composition of OER and OL in the EPI. The identification and equation development were essential steps to provide guidance and basic information on the index.

Project Framework and Data Collection

Predictive Scoring Index methodology was adapted for the analysis of variables and index formation (Inami et al., 2013; Bernabeu-Wittel et al., 2011; Chen & Yang, 2004). The method adaptability enabled the identification of each variable related to the index. Index is the combination of score measurement between two or more types of variable. The OER and OL were identified as the main variables used in the index and equation measurement. OER, OL, fresh fruit bunches (FFB) were obtained from selected palm oil mills using different steriliser systems. Due to confidential purposes, the identity of mills remains unclosed and 25 data were selected from each type of sterilizer systems. The study period was between 2009 and 2013.

Equation Development

The equation developments were formed for the identified variables. Each variable was expressed in a single equation. Eq. (1) shows the calculation of OER.

$$OER = \frac{CPOr}{FFBp} \times 100\% \qquad [1]$$

Where;

OER = Oil extraction rate

CPOr = Crude palm oil recovered

FFB_p = Fresh fruit bunches processed

For the OL, three main sources of palm biomass - Empty Fruit Bunches (EFB), Mesocarp Fibres (MF) and Palm Oil Mill Effluent (POME) - were selected for the equation. The selection process of the palm biomass was based on uniform availability across different steriliser systems in the mills. Eq. (2) represents the calculation for the OL.

$$OL = EFB_{R1} + MF_{R2} + POME_{R3} \qquad [2]$$

Where;

OL = Oil loss

EFB_{R1} = Rate of OL from empty fruit bunches

MF_{R2} = Rate of OL from mesocarp fibres

$POME_{R3}$ = Rate of OL from palm oil mill effluent

However, there is a certain level of OL imposed on the milling process. The standardised OL released into the palm biomass must not exceed 5% (MPOB, 2004). Hence, loss effectiveness (OLE) is defined by the total subtraction between the standard limit and OL

$$OLE = 5.00 - OL \qquad [3]$$

Where;

OLE = Oil loss effectiveness

5.00 = Standard limit permitted for OL

OL = Total oil loss calculation (Eq.2)

OER, OL and OLE Range Scale

Table 1
Oil Extraction Rate (OER) scale

Indicator	OER Ranges		
	CS	CV	CMC
Very High	≥23.00	≥23.00	≥22.00
High	21.30-22.99	21.70-22.99	21.00-21.99
Average	19.60-21.29	20.40-21.69	20.00-20.99
Low	18.00-19.59	19.00-20.39	19.00-19.99
Very Low	<18.00	<19.00	<19.00

Table 2
Oil Loss (OL) scale

Indicator	OL Ranges		
	CS	CV	CMC
Very Low	<1.10	<1.10	<1.30
Low	1.10-1.39	1.10-1.39	1.30-1.69
Average	1.40-1.69	1.40-1.69	1.70-2.09
High	1.70-1.99	1.70-1.99	2.10-2.49
Very High	>2.00	>2.00	>2.50

Table 1 and 2 show the OER and OL ranges respectively, according to different steriliser systems. The range scale was statistically set according to data collected from palm oil mills. Each of the range has indicator remarks whereby positive OER performance increases along with the ranges, while the positive OL performance decreases along the ranges. The purpose of the range table is to categorise the OER and OL data trend series and compare them with the EPI application.

Table 3
Oil Loss Effectiveness (OLE) scale

Indicator	OLE Ranges
<4.01	Very High
4.00 – 3.01	High
3.00 – 2.01	Average
2.00 – 1.01	Low
>1.00	Very Low

The oil loss effectiveness scale is shown in Table 3. Ranges of the OLE is determined based on Equation 3 indicate the palm oil mill effectiveness in maintaining the OL limits set by the MPOB. The increases in OLE ranges indicate positive performance of palm oil mill maintaining its OL level.

Extraction Performance Index (EPI) Equation Formulation

Index equation was defined using the function of geometric average. It is a function of the combination of each factor scores to aggregate the measurement into the equation and the derivation of the EPI equation (Pejman et al., 2015; Brigham & Houston, 2003).

$$EPI = \sqrt{(OER \times OLE)} \qquad [4]$$

Where;
EPI = Extraction performance index
OER = Oil extraction rate (Eq.1)
OLE = Oil loss effectiveness (Eq.3)

Table 4
EPI Indicator

Index	Range Indicator	Remarks
<6.00	Very Poor	Unsatisfied mill performance with very low OER and OLR
6.00 – 6.79	Poor	Poor mill performance with low OER and OLR.
6.80 – 7.49	Average	Average mill performance with average OER and OLR.
7.50 – 8.29	Good	Good mill performance with high OER and OLR.
8.30 – 8.99	Very Good	Very satisfied mill performance with very high OER and OLR.
≥9.00	Excellent	Excellent mill performance with both excellent in OER and OLR standards.

Equation 4 relates to OER and OLE index measurement. It shows the EPI of the composite between variables. Interpretation of EPI range is shown in Table 4 whereby the increase of EPI ranges shows positive result of the palm oil mill extraction performance.

Statistical Analysis

Actual data of the selected palm oil mills (OER and OL) were analysed statistically using SPSS statistical software (Ver.19.0). Data ranges were presented with mean ± SD and interquartile range. The Likert - type scale was used as indicator for each range. The correlation between OER and OL were analysed using Pearson rank correlation coefficient.

RESULTS AND DISCUSSION

Validation of Extraction Performance Index

The final stage in new index development is the validation process. The purpose is to evaluate and measure the index effectiveness and describes the outcome of the variables in the sample selected. Midi et al. (2010) suggests index validation is needed to ensure the index measurement is compatible with field data and able to predict accurately the related measures. The OER and OL data series are shown in Table 1 and Table 2 respectively. For the EPI measurement, OER and OL are expressed in Equation 4 and its interpretation shown in Table 4.

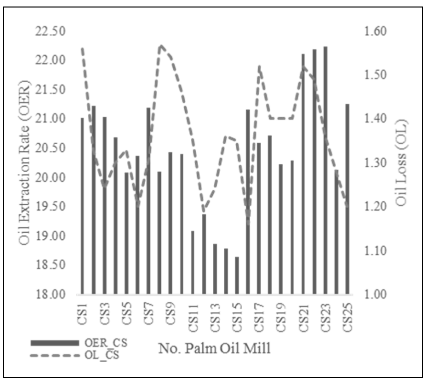

Figure 1. OER vs OL in CS system

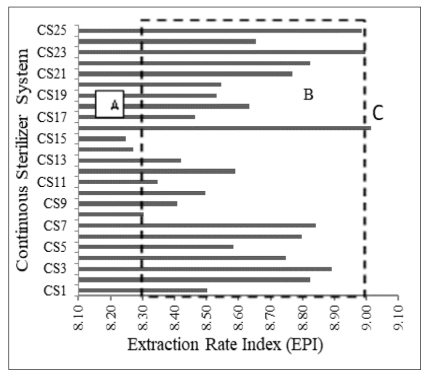

Figure 2. EPI result of CS system

Figure 1 shows data trend of OER and OL in CS system. From the figure, the highest and lowest OER are 22.24 and 18.64 respectively. Table 1 shows overall OER trend recorded 12% higher oil extraction, 68% average oil extraction and 20% low oil extraction. The highest and lowest OL (Table 2) are 1.57 and 1.16 respectively with an overall trend recorded showed 60% low OL and 40% average OL.

EPI result (Figure 2) referred to Table 3 were compared with trends in Figure 1. Highest EPI category is excellent (9.01) and the lowest category is good (8.25). According to Figure 2, the CS16 is identified as "Excellent" EPI with the OER and OL recorded at 21.16 and 1.16 respectively. Based on Table 1, CS16 recorded "Average" category of OER. However, the EPI showed the mill performed at the "Excellent" category. This supported by its oil loss effectiveness (OLE) which recorded high performance (see Table 3) and thus, it has lifted the CS16 level to excellent EPI.

Meanwhile, CS15 recorded lowest EPI in good category. Though its OER recorded low category, 1.35 (Table 1), the OLE result showed high performance; 3.65 in OL management. The OLE result complies with the EPI indicator on good performance as the CS15 achieved high OER and OLE.

The overall EPI for CS system showed two mills (2.7%); Excellent, 21 mills (28%); Very Good and 2 mills (2.7%); Good.

EPI Application of CV System

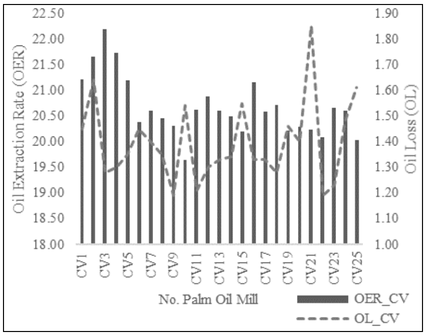

Figure 3. OER vs OL in CV system

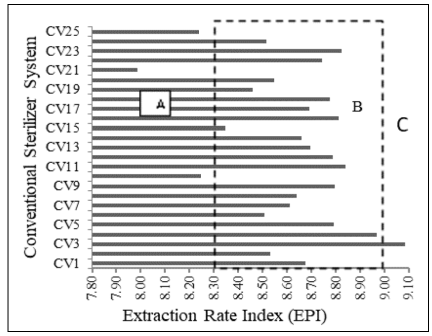

Figure 4. EPI result of CV system

Data trend of OER (Figure 3) showed highest and lowest records at 22.20 and 19.65 respectively. The CV system showed only 8% high oil extraction, 56% average oil extraction and 9% low oil extraction (Table 1). It is also reported 4% high OL, 40% average OL and 56% low OL (Table 2). The highest and lowest OL are 1.85 and 1.19 respectively. Figure 4 shows the EPI of CV system with the highest category 9.09 and lowest category 7.98.

CV3 has the highest EPI category with OER 22.20 and OL 1.28. According to Figure 3 and 4 CV3 recorded excellent performance for its highest OER while maintaining low OL. The OLE (Table 3) also recorded high performance.

Meanwhile CV21 showed lowest EPI in good performance. Despite recording low OER 20.24 (Table 1) and high OL 1.85 (Table 2); CV21 showed good EPI performance. This can be explained by OLE result showing high performance; 3.15 (Table 3). CV21 complied with the EPI in terms of high OLE.

Similar to CS system, the CV system recorded one as "Excellent" (1.3%), while remaining 21 mills (28%) as "Very Good" and 3 mills (4%) as "Good" EPI.

EPI Application of CMC System

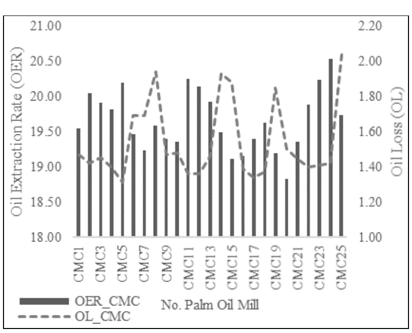

Figure 5. OER vs OL in CMC system

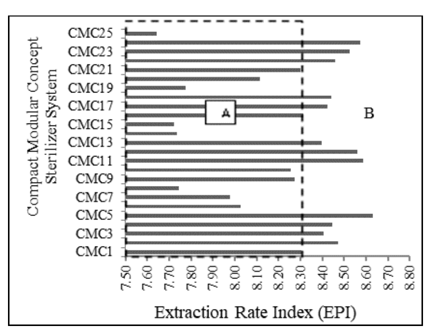

Figure 6. EPI result of CMC system

Unlike the previous steriliser system, data trend of OER for CMC system (Figure 5) recorded 24% average oil extraction, 72% low oil extraction and 4% very low oil extraction with highest OER 20.53 and lowest OER 18.82. As for the OL, 20% average OL and 80% low OL were recorded.

Figure 6 shows the highest EPI is 8.63 and lowest is 7.64. CMC5 showed highest EPI with OER is 20.19 indicating “Very Good” performance. Though its OER is at the average performance, this is supported by OLE (Table 3) at high performance. Hence, the OLE had placed the CMC5 at “Very Good” category in EPI.
Meanwhile, the CMC25 showed lowest EPI, placing it in the good category. Similar to previous CMC5 performance, the CMC25 OER which is at the lowest category is also supported by the high OLE.

In the CMC system, the EPI recorded only two categories of 15 mills namely “Very Good” (20%) and 10 mills (13.3%) as “Good”.

CONCLUSION

In this study, a new method to evaluate palm oil extraction performance was developed based on Predictive Scoring Index methodology. It looked at 75 selected palm oil mills: the EPI showed 4% ‘Excellent’, 76% ‘Very good’ and 20% ‘Good’. For each EPI related to steriliser systems, CS system recorded 2.7% ‘Excellent’, 28% ‘Very good’ and 2.7% ‘Good’ meanwhile CV system recorded 1.3% ‘Excellent’, 28% ‘Very good’ and 4% ‘Good’ performances. The CMC system only recorded ‘Very good’ (20%) and ‘Good’ (13.3%) performances. Among the steriliser systems, only CS and CV achieved the ‘Excellent’ EPI, which indicate excellent efficiency in OER extraction whilst sustaining OL level. Though the CMC system simply achieved ‘Very good’ EPI, the EPI result benefits from upgrading the system to achieve a higher category of EPI.

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REFERENCES

Abdullah, N., & Sulaiman, F. (2013). The Oil Palm Wastes in Malaysia. Chapter 3. In *Biomass Now Sustainable Growth and Use*. Matovic M.D. (ed.), InTech Publishing, Rijeka, Croatia, 75-10.

Adam, M., Sulaiman, A., Said, C., Som, A., Bahruddin, A. S., & Mokhtar, M. N. (2014). Preliminary Study of Oil Palm Decanter Cake Natural Polymer Composite (OPDC-NPC). *Advanced Materials Research, 911*, 40-44.

Baharuddin, A. S., Sulaiman, A., Kim, D. H., Mokhtar, M. N., Hassan, M. A., Wakisaka, M. (2013). Selective component degradation of oil palm empty fruit bunches (OPEFB) using high-pressure steam. *Biomass Bioenergy, 55*, 268-275.

Bernabeu-Wittel, M., Olloro-Baturone, M., Moreno-Gavino, L., Baron-Franco, B., Fuertes, A., Murcia-Zaragoza, J. (2011). Development of a new predictive model for polypathological patients: The PROFUND index. *European Journal of Internal Medicine, 22*, 311-317.

Brigham, E. F., & Houston, J. F. (2003). *Fundamental of financial management: Concise 4th Edition.* Fort Worth, Texas: Harcourt College Publication.

Chang, L., Abdul, R. A., & Basran, Z. (2003). An Economic Perspective of Oil Extraction Rate in the Oil Palm Industry of Malaysia. *Oil Palm Industry Economic Journal, 3*(1), 25-31.

Chen, J. R., & Yang, Y. T. (2004). A predictive risk index for safety performance in process industries. *Journal of Loss Prevention in the Process Industries, 17*, 233-242.

Choong, C., & McKay, A. (2013). Sustainability in the Malaysian palm oil industry. *Journal of Cleaner Production*, 1-7.

Cock, J., Donough, C. R., Oberthur, T., Indrasura, K., Rahmadsyah, Gatot, A. R. (2014). Increasing Palm Oil Yields by Measuring Oil Recovery Efficiency from the Fields to the Mills. *IPNI: Southeast Asia Program*. Indonesia.

Gasperz, V. (2003). Sistem Manajemen Kinerja Terintegrasi: Balanced scorecard dengan six sigma untuk organisasi bisnis dan pemerintah. *Jakarta: PT Gramedia Pustaka Utama.*

Hadi, H., Tamrin, S. B., & Karrupiah, K. (2014). Hazard and Risk Analysis of Different Sterilizer Technology in Palm Oil Mills. *Advances in Environmental Biology, 8*(15), 85-90.

Inami, T., Kataoka, M., Shimura, N., Ishiguro, H., Yanagisawa, R., & Taguchi, H. (2013). Pulmonary Edema Predictive Scoring Index (PEPSI), a New Index to Predict Risk of Reperfusion Pulmonary Edema and Improvement of Hemodynamics in Percutaneous Transluminal Pulmonary Angioplasty. *JACC Cardiovaskular Interventions, 6*(7), 725-736.

Juliano, P., Swiergon, P., Mawson, R., Knoerzer, K., & Augustin, M. A. (2013). Application of Ultrasound for Oil Separation and Recovery of Palm Oil. *Journal of the American Oil Chemists' Society, 90*, 579-588.

Lin, S. W. (2011). *Palm Oil: Edible Oil Processing*. Retrieved from AOCS Lipid Library website: http://lipidlibrary.aocs.org/oilsFats/content.cfm?Itemnumber=40334.

Md. Yunos, N. S., Baharuddin, A. S., Md. Yunos, K. F., Hafid, H. S., Busu, Z., & Mokhtar, M. N. (2015). The physicochemical characteristics of residual oil and fibers from oil palm empty fruit bunches. *Bioresources*, 14-29.

Midi, H., Rana, S., & Sarkar, S. (2010). Binary response modeling and validation of its predictive ability. *Wseas Transactions on Mathematics, 9*(6), 438-447.

MPOB Test Methods. (2004) A compendium of test on palm oil products, palm kernel products, fatty acids, food related products and others Malaysian Palm Oil Board. Kuala Lumpur, Malaysia: Malaysian Palm Oil Board.

Nik Norulaini, N. A., Ahmad, A., Omar, F. M., Banana, A. A., Zaidul, I., & Kadir, M. O. (2008). Sterilization and extraction of palm oil from screw pressed palm fruit fiber using supercritical carbon dioxide. *Separation and Purification Technology*, 272-277.

Nordin, N. I., Ariffin, H., Andou, Y., Hassan, M. A., Shirai, Y., & Nishida, H. (2013). Modification of oil palm mesocarp fiber characteristics using superheated steam treatment. *Molecules, 8*, 9132-9146.

Oberthur, T. (2014). *To increase ol yield from palms, you have to measure it*. Retrieved from The International Plant Nutrition Institute (IPNI) website: http://seap.ipni.net/article/SEAP-3117

Pejman, A., Bidhendi, G. N., Ardenstani, M., Saeedi, M., & Baghvand, A. (2015). A new index for assessing heavy metals contamination in sediments: A case study. *Ecological Indicators, 58*, 365-373.

Rupani, P. F., Singh, R. P., Ibrahim, M. H., & Esa, N. (2010). Review of Current Palm Oil Mill Effluent (POME) Treatment Methods: Vermicomposting as a Sustainable Practice. *World Applied Sciences Journal, 10*(10), 1190-1201.

Sahad, N., Som, A. M., Baharuddin, A. S., Mokhtar, N., Busu, Z., & Sulaiman, A. (2014). Physicochemical characterization of oil palm decanter (OPDC) for residual oil recovery. *Bioresources*, 6361-6372.

Sahad, N. (2015). Characterization of oil palm decanter cake (OPDC) and comparison of residual crude palm oil recovery from OPDC using d-limonene and n-hexane. Unpublished MSc thesis. Universiti Teknologi MARA.

Sambanthamurthi, R., Singh, R., Kadir, A. P., Abdullah, M., & Kushairi, A. (2009). Opportunities for the Oil Palm via Breesing and Biotechnology. In *Breeding Plantation Tree Crops: Tropical Species* (pp. 377-421). New York, USA: Springer Science + Business Publishing.

Sivasothy, K., Basiron, Y., Suki, A., Taha, R. M., Tan, Y. H., & Sulong, M. (2006). Continuous sterilization: The New Paradigm for Modernizing Palm Oil milling. *Journal of Oil Palm Research*, 144-152.

Sivasothy, K., Halim, R. M., & Basiron, Y. (2005). A new system for continuous sterilization of oil palm fresh fruit bunches. *Journal of Oil Palm Research, 17*, 145-151.

Subramaniam, V., Menon, N. R., Sin, H., & Choo, Y. M. (2013). The development of a residual oil recovery system to increase the revenue of a palm oil mill. *Journal of Oil Palm Research, 25*, 116-122.

Salmiyati, Arien, H., Ida, I., & Eko, S. (2014). Oil palm plantations management effects on productivity fresh fruit bunch (FFB). *APCBEE Procedia,* 8, 282-286.

Sulaiman, A., Tabatabaei, M., Yusoff, M. Z., Ibrahim, M. F., Hassan, M. A., & Shirai, Y. (2010). Accelerated start-up of a semi-commercial digester tank treating palm oil mill effluent with sludge seeding for methane production. *World Applied Sciences Journal, 8*(2), 247-258.

Umar, M. S., Jennings, P., & Urmee, T. (2013). Strengthening the palm oil biomass renewable energy industry in Malaysia. *Renewable Energy, 60*, 107-115.

Vincent, C. J., Shamsudin, R., & Baharuddin, A. S. (2014). Pre-treatment of oil palm fruits: A review. *Journal of Food Engineering*, 123-131.

Wan Sharifudin, W., Sulaiman, A., Mokhtar, N., Baharuddin, A. S., Meisam, T., & Busu, Z. (2015). Presence of Residual Oil in Relation to Solid Particle Distribution in Palm Oil Mill Effluent. *Bioresources*, 7591-7603.