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

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 palm oil fresh fruit bunches (FFB) processed in the mill. Previous studies showed
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
Development of Palm Oil Extraction Performance Index

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.

\[
OER = \frac{CPOr}{FFB} \times 100\% \tag{1}
\]

Where:
- \(OER\) = Oil extraction rate
- \(CPOr\) = Crude palm oil recovered
- \(FFB\) = 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.

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

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.

\[
OLE = 5.00 - OL \tag{3}
\]

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*

<table>
<thead>
<tr>
<th>Indicator</th>
<th>CS</th>
<th>CV</th>
<th>CMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>≥23.00</td>
<td>≥23.00</td>
<td>≥22.00</td>
</tr>
<tr>
<td>Low</td>
<td>18.00-19.59</td>
<td>19.00-20.39</td>
<td>19.00-19.99</td>
</tr>
<tr>
<td>Very Low</td>
<td>&lt;18.00</td>
<td>&lt;19.00</td>
<td>&lt;19.00</td>
</tr>
</tbody>
</table>

Table 2

*Oil Loss (OL) scale*

<table>
<thead>
<tr>
<th>Indicator</th>
<th>CS</th>
<th>CV</th>
<th>CMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>&lt;1.10</td>
<td>&lt;1.10</td>
<td>&lt;1.30</td>
</tr>
<tr>
<td>Low</td>
<td>1.10-1.39</td>
<td>1.10-1.39</td>
<td>1.30-1.69</td>
</tr>
<tr>
<td>Average</td>
<td>1.40-1.69</td>
<td>1.40-1.69</td>
<td>1.70-2.09</td>
</tr>
<tr>
<td>High</td>
<td>1.70-1.99</td>
<td>1.70-1.99</td>
<td>2.10-2.49</td>
</tr>
<tr>
<td>Very High</td>
<td>&gt;2.00</td>
<td>&gt;2.00</td>
<td>&gt;2.50</td>
</tr>
</tbody>
</table>

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*

<table>
<thead>
<tr>
<th>Indicator</th>
<th>OLE Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;4.01</td>
<td>Very High</td>
</tr>
<tr>
<td>4.00 – 3.01</td>
<td>High</td>
</tr>
<tr>
<td>3.00 – 2.01</td>
<td>Average</td>
</tr>
<tr>
<td>2.00 – 1.01</td>
<td>Low</td>
</tr>
<tr>
<td>&gt;1.00</td>
<td>Very Low</td>
</tr>
</tbody>
</table>
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).

\[
EPI = \sqrt{\text{OER} \times \text{OLE}}
\]

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

<table>
<thead>
<tr>
<th>Index</th>
<th>Range Indicator</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;6.00</td>
<td>Very Poor</td>
<td>Unsatisfied mill performance with very low OER and OLR</td>
</tr>
<tr>
<td>6.00 - 6.79</td>
<td>Poor</td>
<td>Poor mill performance with low OER and OLR.</td>
</tr>
<tr>
<td>6.80 - 7.49</td>
<td>Average</td>
<td>Average mill performance with average OER and OLR.</td>
</tr>
<tr>
<td>7.50 - 8.29</td>
<td>Good</td>
<td>Good mill performance with high OER and OLR.</td>
</tr>
<tr>
<td>8.30 - 8.99</td>
<td>Very Good</td>
<td>Very satisfied mill performance with very high OER and OLR.</td>
</tr>
<tr>
<td>≥9.00</td>
<td>Excellent</td>
<td>Excellent mill performance with both excellent in OER and OLR standards.</td>
</tr>
</tbody>
</table>

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 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

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

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

Unlike the previous steriliser system, data trend of OER for CMC system (Figure 5) showed highest and lowest records at 21.90 and 19.64 respectively. The CMC system showed only 4% high oil extraction, 68% average oil extraction and 28% low oil extraction (Table 1). It is also reported 4% high OL, 60% average OL and 36% low OL (Table 2). The highest and lowest OL are 2.00 and 1.19 respectively. Figure 6 shows the EPI of CMC system with the highest category 11.20 and lowest category 9.89.

MC4 has the highest EPI category with OER 21.90 and OL 1.20. According to Figure 5 and 6, MC4 recorded excellent performance for its highest OER while maintaining low OL. The OLE (Table 3) also recorded high performance.

Meanwhile MC21 showed lowest EPI in good performance. Despite recording low OER 20.24 (Table 1) and high OL 2.00 (Table 2); MC21 showed good EPI performance. This can be explained by OLE result showing high performance; 3.15 (Table 3). MC21 complied with the EPI in terms of high OLE.

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

ACKNOWLEDGEMENTS

The authors are grateful for the financial support of Ministry of Higher Education (MOHE) Malaysia through Long-term Research Grant Scheme (600-RMI/LRGS 5/3 1/2012) awarded to the Universiti Putra Malaysia and Universiti Teknologi MARA, Shah Alam. Thanks also to FELDA Palm Industries Sdn. Bhd for its technical support to complete this study.

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