Effect of Temperature on the Quality of Fresh Crude Palm Oil at Different Stages of Processing

Rohaya Mohamed Halim* and Ma Ah Ngan*

ABSTRACT

A study was conducted in two palm oil mills to determine the effect of processing temperature at five different processing units on the quality of production oil. Oil samples were collected at the screw press, vibrating screen, clarifier, purifier and vacuum drier for quality analysis. The quality parameters measured were free fatty acid (FFA), peroxide value (PV), DOBI and carotene. Sampling was repeated at the five processing units on different days at 10 min intervals. The data collected were subjected to analysis of variance using SAS package. The differences in values were further evaluated using Duncan's Multiple Range Test. There was no difference in the quality of fresh crude oil at different processing units within the mills. Although the temperatures at the different processing units seemed to have had little effect on the quality of the fresh crude oil in terms of FFA, there were very significant differences in the quality of oil between Mills A and B except for DOBI. The oil produced by Mill B had lower FFA and PV but higher DOBI and carotene values than Mill A. The processing temperatures at different processing units in Mills A and B varied significantly. The process temperatures at Mill B, although within the recommended range, were slightly higher than those of Mill A. The study showed that Mills A and B received 70% and 77% ripe fresh fruit bunches (FFB), respectively. Also, Mill B processed less overripe, rotten and unripe bunches than Mill A. The better quality FFB processed by Mill B could have contributed towards the better quality crude palm oil.

INTRODUCTION

Several factors such as field practice, mill practice, storage and handling are known to affect the quality of crude palm oil (CPO) produced. Among them, field practice is deemed the more important as the product quality is very much dependent on the quality of FFB received by the mill (Chan et al., 1982). Nevertheless, quality deterioration occurs in the

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mill as well. Good quality CPO has a low FFA content, minimum oxidation level which is reflected in a low PV, good bleachability (high DOBI), and is lower in moisture and impurities (Goh, 1991). To produce good quality CPO, the processing steps should be carried out at the lowest temperatures and shortest retention times possible (Chong, 1991).

Mishandling of FFB, in both the field and mill, is detrimental to the quality of CPO (Ng and Southworth, 1983) as most of the CPO quality deterioration results from contamination which causes hydrolysis and oxidation. With the contamination inevitable in all processing, the higher the temperature used, the faster would be the reactions leading to quality deterioration. For example, the rate of oxidation doubles for every 15°C increase in the temperature (Chong, 1991).

In processing for CPO, there is a continuous quality deterioration along the process which may or may not be due to the temperature. Oil quality deterioration may occur during milling, especially at the sterilizer, screw press, digester and clarifier. The sterilization process was found to affect the oil quality, mostly in terms of FFA and bleachability (Aziz Ariffin, 1991). In this process, the FFB are subject to high temperature for an extended time. The presence of oxygen at high temperature causes rapid oxidation. A study by Jacobson (1969) indicated that poor air release during sterilization has an adverse effect on FFA development and poor bleachability.

Deterioration in oil quality also occurs during digestion. This is caused by contamination through high wear and tear of the digester stirring arms. High metal contamination ranging from 9.54 to 27.27 ppm t⁻¹ of FFB processed was reported by Bek-Nielsen (1969a). The FFA rise during digestion was 0.40% to 0.80% (Wolvesperges, 1969).

During pressing, additional metal wear occurs, contributing to iron contamination. It was reported by Bek-Nielsen (1969b) that the rate of iron contamination is 12.27 ppm t⁻¹ of FFB processed.

Crude oil slurry from the screw press is normally retained in the clarifier for 2–3 hr for oil separation. This condition leads to oxidative degradation. Recycling oil from the sludge pit to the clarifier increases the metal contamination and also promotes oxidation of the oil.

The purpose of this study was to evaluate the effect of temperature on the quality of CPO at various processing stages in two palm oil mills.

**METHODOLOGY**

Two mills, A and B, with FFB processing capacities of 54 t hr⁻¹ and 20 t hr⁻¹, respectively, were selected for the study. Mill A processed both its own (18%) and purchased FFB (82%) while Mill B only processed its own FFB.

Fresh crude oil was collected every 10 min from five processing stages. The approximate retention times for the oil between the processing units (based on the calculations in Appendix I) are shown in Table 1.

**TABLE 1. SAMPLING POINTS AND RETENTION TIMES BETWEEN PROCESSING UNITS**

<table>
<thead>
<tr>
<th>Processing unit</th>
<th>Sampling point</th>
<th>Retention time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screw press</td>
<td>1</td>
<td>–</td>
</tr>
<tr>
<td>Vibrating screen</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Clarifier</td>
<td>3</td>
<td>130</td>
</tr>
<tr>
<td>Purifier</td>
<td>4</td>
<td>60</td>
</tr>
<tr>
<td>Vacuum dryer</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

Six samples of 250 ml each were collected at every sampling point. The temperature at each point was recorded. The samples before the vibrating screen were centrifuged to remove debris. The samples were analysed for FFA, DOBI, PV and carotene content using PORIM Test Methods (1995).

The FFB received by each mill were graded using PORLA Ripeness Standard to assess the quality of raw materials received. Five hundred bunches were graded and grouped into five categories – unripe, underripe, ripe, overripe and rotten.

**RESULTS AND DISCUSSION**

The oil temperatures at the different processing units are shown in Table 2 for both Mills A and B.

The temperatures at different processing units in Mills A and B varied significantly. However, all the
Temperature (°C) of Oil at the Different Processing Units in Mills A and B

<table>
<thead>
<tr>
<th>Processing unit</th>
<th>Mill**</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>[Mean]</td>
<td>Range</td>
<td>[Mean]</td>
<td>Mean (A and B)</td>
</tr>
<tr>
<td>Digester</td>
<td>83.00 - 94.00</td>
<td>[87.88]</td>
<td>85.00 - 95.00</td>
<td>[92.00]</td>
<td>89.94</td>
</tr>
<tr>
<td>Vibrating screen</td>
<td>81.00 - 88.00</td>
<td>[85.38]</td>
<td>90.00 - 98.00</td>
<td>[94.00]</td>
<td>89.69</td>
</tr>
<tr>
<td>Clarifier</td>
<td>85.00 - 90.00</td>
<td>[86.25]</td>
<td>85.00 - 90.00</td>
<td>[88.75]</td>
<td>87.50</td>
</tr>
<tr>
<td>Purifier</td>
<td>71.00 - 84.00</td>
<td>[79.13]</td>
<td>78.00 - 88.00</td>
<td>[84.25]</td>
<td>81.69</td>
</tr>
<tr>
<td>Vacuum dryer</td>
<td>70.00 - 75.00</td>
<td>[71.63]</td>
<td>75.00 - 80.00</td>
<td>[76.50]</td>
<td>74.06</td>
</tr>
</tbody>
</table>

Note: ** difference statistically significant.

Average temperatures at the processing units were within the industry’s normal range.

Free Fatty Acids (FFA)

The FFA of the fresh crude oil at the different processing units are presented in Table 3. Although Mill B used higher processing temperatures, it produced better oil than Mill A because of the better quality FFB received. At the beginning of the process assessed (screw press), the oil from Mill B had 3.13% FFA. This increased to 3.43%, or by 9.58%, at the end of the process. On the other hand, the oil in Mill A started off with 4.03% FFA, and deteriorated to 4.33%, an increase of only 7.44%. Mill A, therefore, produced better oil in terms of FFA.

The better quality FFB received by Mill B can be seen in Table 4. It received more ripe bunches than Mill A (77.00% vs. 70.25%) and less overripe (7.13% vs. 8.50%) and rotten (6.83% vs. 9.50%) bunches. As is well known, overripe and rotten bunches are the major contributors to high FFA.

Oxidative Stability

Peroxide Value (PV)

The PVs are presented in Table 5. Both the mills produced oils at all stages with values far below 3.0 meq. kg⁻¹, the maximum recommended by MPOB. However, Bek-Nielsen (1969a) found that freshly extracted oil had generally zero PV. Mill B produced the better oil, but again, this was attributed to the better FFB processed. The data suggested that very little oxidative deterioration occurred during processing in both mills.

Bleachability Index

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TABLE 4. RIPENESS OF BUNCHES RECEIVED BY MILLS A AND B

<table>
<thead>
<tr>
<th>Bunch ripeness</th>
<th>Mill** A Range [Mean]</th>
<th>Mill** B Range [Mean]</th>
<th>Mean (A and B)</th>
<th>CV (A and B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underripe</td>
<td>2.00 - 8.00 [5.52]</td>
<td>4.00 - 8.00 [5.88]</td>
<td>5.70</td>
<td>35.41</td>
</tr>
<tr>
<td>Unripe</td>
<td>3.00 - 8.00 [6.01]</td>
<td>2.00 - 6.00 [3.95]</td>
<td>4.98</td>
<td>38.98</td>
</tr>
<tr>
<td>Ripe</td>
<td>63.00 - 75.00 [70.25]</td>
<td>70.00 - 88.00 [77.00]</td>
<td>73.63</td>
<td>9.03</td>
</tr>
<tr>
<td>Overripe</td>
<td>4.00 - 15.00 [8.50]</td>
<td>5.00 - 10.00 [7.13]</td>
<td>7.81</td>
<td>36.57</td>
</tr>
<tr>
<td>Rotten</td>
<td>6.00 - 13.00 [9.50]</td>
<td>2.00 - 10.00 [6.83]</td>
<td>8.16</td>
<td>33.53</td>
</tr>
</tbody>
</table>

Note: ** difference statistically significant.

TABLE 5. PV OF FRESH CRUDE OIL FROM THE DIFFERENT PROCESSING STAGES AT MILLS A AND B

<table>
<thead>
<tr>
<th>Processing unit</th>
<th>Mill** A Range [Mean]</th>
<th>Mill** B Range [Mean]</th>
<th>Mean (A and B)</th>
<th>CV (A and B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screw press</td>
<td>0.20 - 0.48 [0.35]</td>
<td>0.10 - 0.46 [0.26]</td>
<td>0.30</td>
<td>40.79</td>
</tr>
<tr>
<td>Vibrating screen</td>
<td>0.20 - 0.48 [0.37]</td>
<td>0.10 - 0.48 [0.27]</td>
<td>0.32</td>
<td>39.62</td>
</tr>
<tr>
<td>Clarifier</td>
<td>0.20 - 0.52 [0.39]</td>
<td>0.12 - 0.54 [0.28]</td>
<td>0.34</td>
<td>41.25</td>
</tr>
<tr>
<td>Purifier</td>
<td>0.22 - 0.57 [0.44]</td>
<td>0.12 - 0.64 [0.30]</td>
<td>0.37</td>
<td>44.24</td>
</tr>
<tr>
<td>Vacuum dryer</td>
<td>0.23 - 0.62 [0.48]</td>
<td>0.14 - 0.65 [0.31]</td>
<td>0.40</td>
<td>4408</td>
</tr>
</tbody>
</table>

Note: ** difference statistically significant.

The DOBI of fresh crude oil from Mills A and B were not significantly different (Table 6). The DOBI values for Mills A and B in the oils produced were 2.29 to 2.82 and 2.44 to 2.91, respectively. A higher DOBI reflects an oil with less oxidation. The oil from Mill B suffered less quality deterioration than that from Mill A but the difference was marginal. The DOBI data showed that both the mills produced average quality oil. Siew (1989) suggested that an oil with a DOBI above 3 can be bleached easily.

CONCLUSION

• This study showed that the processing temperature had little effect on the FFA of the fresh crude oil.

• Mill B received and processed better quality FFB resulting in better quality CPO with much lower FFA than Mill A.

• The oil produced by Mill B had lower PV, higher DOBI and carotene content than that from Mill A. These factors may directly be related to the overall quality of FFB received and processed by the mills.

Carotene Content

The carotene contents of the fresh crude oil in Mills A and B were highly significantly different. The oil samples collected from Mills A and B showed minimal loss in carotene during processing at the different processing units (Table 7). The carotene content in oil produced at Mill A was 500 to 683 ppm, and in Mill B 621 to 684 ppm.
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### TABLE 6. DOBI OF FRESH CRUDE OIL FROM DIFFERENT PROCESSING STAGES AT MILLS A AND B

<table>
<thead>
<tr>
<th>Processing unit</th>
<th>Range A [Mean]</th>
<th>Range B [Mean]</th>
<th>Mean (A and B)</th>
<th>CV (A and B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screw press</td>
<td>2.37 - 2.87 [2.65]</td>
<td>2.46 - 2.97 [2.76]</td>
<td>2.70</td>
<td>7.33</td>
</tr>
<tr>
<td>Vibrating screen</td>
<td>2.49 - 2.98 [2.69]</td>
<td>2.52 - 3.01 [2.72]</td>
<td>2.70</td>
<td>6.29</td>
</tr>
<tr>
<td>Clarifier</td>
<td>2.20 - 2.86 [2.57]</td>
<td>2.55 - 3.07 [2.78]</td>
<td>2.67</td>
<td>8.04</td>
</tr>
<tr>
<td>Vacuum dryer</td>
<td>2.29 - 2.82 [2.54]</td>
<td>2.44 - 2.91 [2.65]</td>
<td>2.59</td>
<td>7.32</td>
</tr>
</tbody>
</table>

### TABLE 7. CAROTENE CONTENTS OF FRESH CRUDE OIL TAKEN FROM DIFFERENT PROCESSING UNITS AT MILLS A AND B

<table>
<thead>
<tr>
<th>Processing unit</th>
<th>Range A [Mean]</th>
<th>Range B [Mean]</th>
<th>Mean (A and B)</th>
<th>CV (A and B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarifier</td>
<td>508 - 690 [587]</td>
<td>626 - 675 [649]</td>
<td>618</td>
<td>9.02</td>
</tr>
</tbody>
</table>

Note: ** difference statistically significant.

### RECOMMENDATION

Intensive monitoring of harvesting and processing operations must be practised by both estate and mill personnel to ensure ripe bunches and minimize bruising and damage to the fruits. It has been emphasized by Olie and Tjeng (1974) that good quality palm oil is made in the field not in the factory. Estate personnel must maintain harvesting standards following the MPOB guidelines and adhere to the optimum harvesting round to ensure that FFB are harvested at the optimum ripeness stage.

Although the milling operation only caused minimal oil quality deterioration, installation of stainless steel piping, storage tanks and coated tanks to avoid metal contamination should be initiated to further minimize metal contamination which has a detrimental effect on oil quality.

### ACKNOWLEDGEMENT

The authors wish to thank the Director-General of MPOB for permission to publish these findings. They would also like to acknowledge the contribution of Dr Osman Atil, Ir Ravi Menon, Dr K. Sivasothy and Dr Chong Chiew Let for their advice and assistance. Thanks are also due to Mashuri, Muhammad, Kamaruddin, Romzi and Asri for technical assistance in this project. The co-operation of the mills involved is also appreciated.

### REFERENCES


APPENDIX 1. Calculation of Retention Time for Oil at Different Processing Units

1) Press to vibrating screen = 4 min (by observation)

2) Crude oil tank to ex-continuous settling (C.S.) tank.
   C.S. tank capacity = 60 t
   Mill capacity = 54 t hr\(^{-1}\)
   At OER 18%: total oil produced = 0.18 x 54 t hr\(^{-1}\) = 9.72 t hr\(^{-1}\)
   Oil in diluted crude oil = 35%
   ∴ Diluted crude oil = \(\frac{9.72 \text{ t hr}^{-1} \times 100}{35}\) = 27.78 t hr\(^{-1}\)
   Retention time = \(\frac{60 \text{ t}}{27.78 \text{ t hr}^{-1}}\) = 2.2 hr = 130 min

3) Pure oil tank to ex-purifier
   Pure oil tank capacity = 10 t
   Purifier throughput = 10 t hr\(^{-1}\)
   Retention time in tank = \(\frac{10}{10 \text{ t hr}^{-1}}\) = 1 hr = 60 min

4) Ex purifier to ex-vacuum dryer
   Vacuum dryer throughput = 10 t hr\(^{-1}\)
   Volume of oil in pipe from purifier to vacuum dryer:
   20 m long x 0.1 m diameter
   Volume = area of cross section x length = \(\pi d^2 x \frac{20}{4}\)
   = 20 x 3.1428 x (0.1)^2 = 0.007857 m\(^3\) x 20m = 0.1571 m\(^3\)
   At density 0.87 t m\(^{-3}\)
   Quantity of oil = 0.1571 m\(^3\) x 0.87 t m\(^{-3}\) = 0.1367 t
   Pump throughput = 10 t hr\(^{-1}\)
   Retention time = \(\frac{0.1367 \text{ t}}{10 \text{ t hr}^{-1}}\) = 0.01367 hr = 0.82 min = 1 min