POCKETBOOK OF OIL PALM USES
Malaysian Palm Oil Board, 2017

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FOREWORD

This is the seventh edition of this *Pocketbook of Oil Palm Uses* which is an introduction to oil palm, palm and palm kernel oils and their uses. The pocketbook has been well received since its first publication in May 1987. Its popularity, coupled with the many new innovative uses for palm products continually being developed, has necessitated its regular updating for the benefit of the users of Malaysian palm products.

It is hoped that the pocketbook will serve well as a reference to readers in their understanding of the versatility of the oil palm and its products.

PALM OIL – THE EXCELLENT CHOICE

Dr Ahmad Kushairi Din
Director-General
Malaysian Palm Oil Board
COORDINATORS

Rosidah Radziah Director, Product Development and Advisory Services Division
Fauziah Arshad Head, Technical Advisory Services (TAS) Unit
Juanita Lourdes Nathan Research Officer, TAS Unit
Dr Loh Soh Kheang Head, Energy and Environment Unit

CONTRIBUTORS

Economy & Industry Development Division
Balu Nambiappan Director
Norihan Husain Head, Industry Development Unit
Nik Abdullah Nik Idris Research Officer, Industry Development Unit
Dayang Nazrima Shahari Research Officer, Industry Development Unit

Food Uses
Dr Miskandar Mat Sahri Head, Protein and Food Technology Unit
Noor Lida Habi Mat Din Senior Research Officer, Protein and Food Technology Unit
Rafidah Abdul Hamid Research Officer, Protein and Food Technology Unit

Palm Oil Specifications
Dr Halimah Muhamad Head, Analytical and Quality Development Unit
Farah Khuwailah Research Officer, Analytical and Quality Development Unit

Nutrition
Dr Nagendran Balasundram Head, Nutrition Unit
Dr Kanga Rani Selvaduray Senior Research Officer, Nutrition Unit
Dr Zaida Zainal Principal Research Officer, Nutrition Unit
Dr Syed Fairus Syed Abu Bakar Senior Research Officer, Metabolics Unit

Advanced Oleochemical Technology Development Division
Dr Hazimah Abu Hassan Director
Dr Yeong Shoot Kian Head, Synthesis and Product Development Unit
Razmah Ghazali Head, Quality and Environmental Assessment Unit
Rosnah Ismail Senior Research Fellow
Dr Zainab Idris Head, Process Engineering and Design Unit
Zafarizal Aldrin Azizul Hasan Head, Consumer Product Development Unit

Engineering and Processing Division
Dr Loh Soh Kheang Head, Energy and Environment Unit
Dr Astimar Abdul Aziz Head, Biomass Technology Unit

Animal Feed from Oil Palm Biomass
Dr Miskandar Mat Sahri Head, Protein and Food Technology Unit

Sustainability of the Malaysian Oil Palm Industry
Nik Mohd Aznizan Nik Head, Sustainability, Conservation and Certification Unit
Ibrahim

vii
CHAPTER 1:
OIL PALM IN MALAYSIA
INTRODUCTION

The oil palm (*Elaeis guineensis*) was brought to Malaysia as an ornamental in 1870. Since 1960, its area has increased rapidly, in 2015 reaching 5.6 million hectares (Figure 1), and it has become the most important crop in the country. The oil palm area by ownership category is shown in Table 1. Private estates, Government agencies (FELDA, FELCRA, RISDA, etc.) and independent smallholders own 61.6%, 23.6% and 15.0%, respectively, of it.

The oil palm planted is the tenera hybrid which (per hectare) yields about 4.0 tonnes palm oil, 0.5 tonne palm kernel oil (PKO) and 0.6 tonne palm kernel cake (PKC).

---

**TABLE 1. OIL PALM PLANTED AREA BY OWNERSHIP CATEGORY: 2005 - 2015 (MILLION HECTARES)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Smallholders</td>
<td>0.43</td>
<td>0.65</td>
<td>0.70</td>
<td>0.69</td>
<td>0.75</td>
<td>0.81</td>
<td>0.88</td>
</tr>
<tr>
<td>FELDA</td>
<td>0.65</td>
<td>0.71</td>
<td>0.70</td>
<td>0.71</td>
<td>0.70</td>
<td>0.69</td>
<td>0.71</td>
</tr>
<tr>
<td>FELCRA</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
<td>0.17</td>
<td>0.17</td>
<td>0.17</td>
<td>0.18</td>
</tr>
<tr>
<td>RISDA</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>State Agencies</td>
<td>0.32</td>
<td>0.32</td>
<td>0.32</td>
<td>0.30</td>
<td>0.31</td>
<td>0.33</td>
<td>0.35</td>
</tr>
<tr>
<td>Private Estates</td>
<td>2.41</td>
<td>2.93</td>
<td>3.04</td>
<td>3.13</td>
<td>3.22</td>
<td>3.32</td>
<td>3.45</td>
</tr>
<tr>
<td>TOTAL</td>
<td>4.05</td>
<td>4.85</td>
<td>5.00</td>
<td>5.08</td>
<td>5.23</td>
<td>5.39</td>
<td>5.64</td>
</tr>
</tbody>
</table>

*Source: MPOB Statistics 2016*

---

*Figure 1. Malaysia: Oil Palm Planted Area (1975-2015)*
The crop is first harvested 30 months after field planting and has an economic life of 25 years. The fruit is the size of a date, borne in large bunches of 10 - 20 kg weight. A bunch can have up to 2,000 fruits, each a hard kernel (seed) in a shell (endocarp) covered by a fleshy mesocarp. The mesocarp contains about 49% oil and the kernel about 50%. The two oils have very different compositions. Palm oil (from the mesocarp) contains mainly palmitic (C16:0) and oleic (C18:1), the two most common fatty acids in natural oils and fats, and is about 50% saturated. Palm kernel oil contains mainly lauric (C12:0) and is more than 80% saturated.

PRODUCTION OF PALM AND PALM KERNEL OILS

PALM OIL

Palm oil production in Malaysia has increased tremendously over the years - from 7.81 million tonnes in 1995 to 19.96 million tonnes in 2015 (Table 2, Figure 2).

<table>
<thead>
<tr>
<th>Year</th>
<th>Tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>7,810,546</td>
</tr>
<tr>
<td>2000</td>
<td>10,842,095</td>
</tr>
<tr>
<td>2005</td>
<td>14,961,654</td>
</tr>
<tr>
<td>2010</td>
<td>16,993,717</td>
</tr>
<tr>
<td>2013</td>
<td>19,216,459</td>
</tr>
<tr>
<td>2014</td>
<td>19,667,016</td>
</tr>
<tr>
<td>2015</td>
<td>19,961,581</td>
</tr>
</tbody>
</table>

Source: MPOB Statistics 2016

Palm Oil Fact

Oil palm (Elaeis guineensis) was brought to Malaysia as an ornamental in 1870. Since 1960, its area has increased rapidly in 2014 reaching 5.2 million hectares, and it has become the most important crop in the country.
Palm Kernel Oil

In 1995, Malaysia produced 1.04 million tonnes palm kernel oil, rising to 2.28 million tonnes in 2015 (Table 3, Figure 3). Before 1970, most of the palm kernel produced were exported. Since 1979, they are crushed locally to produce kernel oil and cake.

**TABLE 3. MALAYSIA- PRODUCTION OF CPKO**

<table>
<thead>
<tr>
<th>Year</th>
<th>Tonnes ('000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>1,036,538</td>
</tr>
<tr>
<td>2000</td>
<td>1,384,685</td>
</tr>
<tr>
<td>2005</td>
<td>1,842,628</td>
</tr>
<tr>
<td>2010</td>
<td>2,014,942</td>
</tr>
<tr>
<td>2013</td>
<td>2,269,822</td>
</tr>
<tr>
<td>2014</td>
<td>2,277,382</td>
</tr>
<tr>
<td>2015</td>
<td>2,276,466</td>
</tr>
</tbody>
</table>

*Source: MPOB Statistics 2016.*

![Cross section of a palm fruit](image)

*Figure 3. Malaysia: Production of Crude Palm Kernel Oil (1975 – 2015).*
Malaysia is the second largest producer of palm oil in the world, being overtaken by Indonesia in 2006. The top producing countries are shown in Table 4 while Table 5 shows the world production of palm kernel oil.

TABLE 4. WORLD PRODUCTION OF PALM OIL ('000 TONNES)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>7,810</td>
<td>10,842</td>
<td>14,962</td>
<td>18,785</td>
<td>19,216</td>
<td>19,667</td>
<td>19,961</td>
</tr>
<tr>
<td>Indonesia</td>
<td>4,220</td>
<td>7,050</td>
<td>14,100</td>
<td>26,900</td>
<td>28,500</td>
<td>30,800</td>
<td>33,400</td>
</tr>
<tr>
<td>Nigeria</td>
<td>660</td>
<td>740</td>
<td>800</td>
<td>940</td>
<td>970</td>
<td>1,010</td>
<td>940</td>
</tr>
<tr>
<td>Colombia</td>
<td>353</td>
<td>524</td>
<td>673</td>
<td>967</td>
<td>1,040</td>
<td>1,120</td>
<td>1,273</td>
</tr>
<tr>
<td>Cote' d'Ivoire</td>
<td>300</td>
<td>278</td>
<td>290</td>
<td>405</td>
<td>415</td>
<td>420</td>
<td>522</td>
</tr>
<tr>
<td>Thailand</td>
<td>316</td>
<td>525</td>
<td>700</td>
<td>1,780</td>
<td>1,970</td>
<td>1,930</td>
<td>1,833</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>225</td>
<td>336</td>
<td>310</td>
<td>520</td>
<td>500</td>
<td>530</td>
<td>500</td>
</tr>
<tr>
<td>Ecuador</td>
<td>178</td>
<td>218</td>
<td>319</td>
<td>543</td>
<td>495</td>
<td>515</td>
<td>530</td>
</tr>
<tr>
<td>Others</td>
<td>1,149</td>
<td>1,354</td>
<td>1,798</td>
<td>3,043</td>
<td>3,207</td>
<td>3,331</td>
<td>3,599</td>
</tr>
<tr>
<td>TOTAL</td>
<td>15,211</td>
<td>21,867</td>
<td>33,952</td>
<td>53,883</td>
<td>56,313</td>
<td>59,323</td>
<td>62,559</td>
</tr>
</tbody>
</table>

Sources: Oil World 2016 and MPOB 2016

Table 6 shows the productivity of the major oil crops. Oil palm is the highest yielding, producing 4.28 tonnes of oil (both palm and kernel oils) per hectare per year. But this may be just the tip of the iceberg. Figure 4 shows the palm’s potential.

Table 6. PRODUCTIVITY OF VARIOUS MAJOR OIL CROPS (2013/2014)

<table>
<thead>
<tr>
<th>Oil crop</th>
<th>Calculated Oil Yield (tonnes/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm oil</td>
<td>3.61*</td>
</tr>
<tr>
<td>Palm kernel</td>
<td>0.40</td>
</tr>
<tr>
<td>Soybean</td>
<td>0.41</td>
</tr>
<tr>
<td>Cotton</td>
<td>0.14</td>
</tr>
<tr>
<td>Groundnut</td>
<td>0.15</td>
</tr>
<tr>
<td>Sunflower</td>
<td>0.62</td>
</tr>
<tr>
<td>Rape</td>
<td>0.74</td>
</tr>
<tr>
<td>Coconut</td>
<td>0.31</td>
</tr>
</tbody>
</table>

*Global Average
Palm oil is the most traded oil in the world. In 2015, its exports reached 48.2 million tonnes, of which Malaysia's share was 36.1%. The top major exporting countries of palm and palm kernel oils are shown in Tables 7 and 8, respectively.

**TABLE 7. WORLD PALM OIL EXPORTS (’000 TONNES)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>6,513</td>
<td>9,081</td>
<td>13,445</td>
<td>17,575</td>
<td>18,147</td>
<td>17,278</td>
<td>17,454</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1,856</td>
<td>4,139</td>
<td>10,436</td>
<td>19,094</td>
<td>21,471</td>
<td>22,080</td>
<td>26,548</td>
</tr>
<tr>
<td>Cote' d'Ivoire</td>
<td>120</td>
<td>72</td>
<td>122</td>
<td>279</td>
<td>200</td>
<td>261</td>
<td>471</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>220</td>
<td>336</td>
<td>295</td>
<td>525</td>
<td>500</td>
<td>525</td>
<td>513</td>
</tr>
<tr>
<td>Others</td>
<td>1,485</td>
<td>1,391</td>
<td>2,213</td>
<td>3,338</td>
<td>3,657</td>
<td>3,452</td>
<td>3,244</td>
</tr>
<tr>
<td>TOTAL</td>
<td>10,194</td>
<td>15,019</td>
<td>26,511</td>
<td>40,811</td>
<td>43,975</td>
<td>43,596</td>
<td>48,230</td>
</tr>
</tbody>
</table>

Sources: OIL WORLD 2016 and MPOB 2016.

**TABLE 8. WORLD PALM KERNEL OIL EXPORTS (’000 TONNES)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>391</td>
<td>520</td>
<td>851</td>
<td>1,085</td>
<td>1,171</td>
<td>1,111</td>
<td>1,067</td>
</tr>
<tr>
<td>Indonesia</td>
<td>311</td>
<td>579</td>
<td>1,043</td>
<td>1,669</td>
<td>1,722</td>
<td>1,628</td>
<td>1,890</td>
</tr>
<tr>
<td>Cote' d'Ivoire</td>
<td>16</td>
<td>14</td>
<td>0</td>
<td>17</td>
<td>15</td>
<td>18</td>
<td>76</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>11</td>
<td>29</td>
<td>29</td>
<td>38</td>
<td>50</td>
<td>51</td>
<td>55</td>
</tr>
<tr>
<td>Nigeria</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Others</td>
<td>64</td>
<td>74</td>
<td>175</td>
<td>253</td>
<td>281</td>
<td>313</td>
<td>218</td>
</tr>
<tr>
<td>TOTAL</td>
<td>796</td>
<td>1,220</td>
<td>2,099</td>
<td>3,065</td>
<td>3,272</td>
<td>3,152</td>
<td>3,309</td>
</tr>
</tbody>
</table>

Sources: OIL WORLD 2016 and MPOB 2016.
Palm oil is priced competitively vis-à-vis the other major vegetable oils. By virtue of being the world’s largest traded oil (accounting for 57% of the total trade), it should be the price leader but, more often than not, trades at a discount to its competitors.
Palm oil is from the mesocarp of the oil palm fruit. The oil is refined physically to a golden yellow colour.

**Properties**

Palm oil has a balanced fatty acid composition with about equal saturated and unsaturated fatty acids. Palmitic (44 - 45%) and oleic (39 – 40%) are the major components with linoleic (10 - 11%) and a trace of linolenic. The low linoleic and virtual absence of linolenic make the oil stable to oxidation. Malaysian palm oil has a narrow compositional range as found from several surveys. Its specifications are given in MS 814:2007 (Table 9).

Palm oil is unique among vegetable oils in having mainly unsaturated fatty acids at the 2- position of its triglycerides. The appreciable monosaturated (POO, OPO and PLO) and disaturated (POP and PPO) TAGs* - allow it to be easily fractionated into two main products, olein and stearin. A wide range of fractions with different properties to suit the different requirements of the food industry can be further made through dry fractionation.

* P = Palmitic  O = Oleic  L = Lauric

**TABLE 9. CHARACTERISTICS FOR MALAYSIAN CRUDE PALM OIL**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Observed value (min. to max.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent density, g/ml at 50°C</td>
<td>0.8896 to 0.8896</td>
</tr>
<tr>
<td>Refractive index nD. 50°C</td>
<td>1.4521 to 1.4541</td>
</tr>
<tr>
<td>Saponification value, mg KOH/g oil</td>
<td>194 to 205</td>
</tr>
<tr>
<td>Unsaponifiable matter, %</td>
<td>0.19 to 0.44</td>
</tr>
<tr>
<td>Fatty acid composition (wt% as methyl esters)</td>
<td></td>
</tr>
<tr>
<td>C12:0</td>
<td>0.0 to 0.5</td>
</tr>
<tr>
<td>C14:0</td>
<td>0.9 to 1.5</td>
</tr>
<tr>
<td>C16:0</td>
<td>39.2 to 45.8</td>
</tr>
<tr>
<td>C16:1</td>
<td>0 to 0.4</td>
</tr>
<tr>
<td>C18:0</td>
<td>3.7 to 5.1</td>
</tr>
<tr>
<td>C18:1</td>
<td>37.4 to 44.1</td>
</tr>
<tr>
<td>C18:2</td>
<td>8.7 to 12.5</td>
</tr>
<tr>
<td>C18:3</td>
<td>0.0 to 0.6</td>
</tr>
<tr>
<td>C20:0</td>
<td>0.0 to 0.5</td>
</tr>
<tr>
<td>Iodine value (Wijs)</td>
<td>50.4 to 53.7</td>
</tr>
<tr>
<td>Slip melting point, °C</td>
<td>33.8 to 39.2</td>
</tr>
<tr>
<td>Total carotenoids (as β-carotene), mg/kg</td>
<td>474 to 689</td>
</tr>
</tbody>
</table>

*Note: The characteristics of processed palm oil do not differ much from those of crude palm oil with the exception of carotenoids which are destroyed during refining.*

*Source: MS 814:2007.*
General Description

Palm olein is the liquid fraction from fractionating palm oil. In the physical process, palm oil is cooled and the crystals formed filtered out. Basically, the liquid fraction is palm olein and the solid fraction palm stearin. Both olein and stearin are major products used in food.

Palm olein is fully liquid at ambient in warm climes. It can be blended with other vegetable oils to obtain even more liquid oils to withstand lower temperature. For example, palm olein with >70% soft oils, such as soybean, corn or canola oils, remains clear at 0°C for at least 5 h. The oxidative stability of the soft oils are extended and improved by palm olein.

There are two major grades of palm olein: Standard (IV 56 – 59, Cloud Point 10°C) and Super (IV >60, Cloud Point 2 - 5°C). The specifications of standard Malaysian palm olein are given in MS 816:2007 (Table 10). Super is for the cooler climes.

Properties of Standards Palm Olein

Both standard and super oleins are suitable as cooking oils, especially for frying (both deep and shallow) because of their high stability. Olein is rich in tocotrienols, which are preferentially partitioned to it from stearin in fractionating palm oil.

Palm Oil Fact

Globally, Malaysia is the second largest producer of palm oil.
TABLE 10. IDENTITY CHARACTERISTICS FOR MALAYSIAN PALM OLEIN

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Observed value (min. to max.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent density, g/ml at 40°C</td>
<td>0.8969 to 0.8977</td>
</tr>
<tr>
<td>Refractive index nD, 40°C</td>
<td>1.4589 to 1.4592</td>
</tr>
<tr>
<td>Saponification value, mg KOH/g oil</td>
<td>194 to 202</td>
</tr>
<tr>
<td>Unsaponifiable matter, %</td>
<td>0.3 to 1.30</td>
</tr>
<tr>
<td>Fatty acid composition (wt% as methyl esters)</td>
<td></td>
</tr>
<tr>
<td>C12:0</td>
<td>0.2 to 0.4</td>
</tr>
<tr>
<td>C14:0</td>
<td>0.9 to 1.2</td>
</tr>
<tr>
<td>C16:0</td>
<td>38.2 to 42.9</td>
</tr>
<tr>
<td>C16:1</td>
<td>0.1 to 0.3</td>
</tr>
<tr>
<td>C18:0</td>
<td>3.7 to 4.8</td>
</tr>
<tr>
<td>C18:1</td>
<td>39.8 to 43.9</td>
</tr>
<tr>
<td>C18:2</td>
<td>10.4 to 12.7</td>
</tr>
<tr>
<td>C18:3</td>
<td>0.1 to 0.6</td>
</tr>
<tr>
<td>C20:0</td>
<td>0.2 to 0.6</td>
</tr>
<tr>
<td>Iodine value (Wijs)</td>
<td>56.0 to 59.1</td>
</tr>
<tr>
<td>Slip melting point, °C</td>
<td>19.2 to 23.6</td>
</tr>
<tr>
<td>Total carotenoids (as β-carotene), mg/kg</td>
<td>500 to 1200</td>
</tr>
</tbody>
</table>

Note: The identity characteristics of processed palm oil do not differ much from those of crude palm olein with the exception of carotenoids which are destroyed during refining.

Properties of Super Olein

Superolein is olein with higher IV (>60). The general characteristics of the Malaysian oil are given in Table 11. It has better clarity and a lower tendency to cloud than standard olein because of its much lower solid fat content (Figure 7). It is suitable as a cooking and frying oil. Blending standard or super olein with unsaturated oils gives oils with different compositions and clarity to cater for the different market requirements.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Range</th>
<th>Mean</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent density, g/ml at 30°C</td>
<td>0.9042–0.9054</td>
<td>0.9046</td>
<td>0.0003</td>
</tr>
<tr>
<td>Refractive index nD30°C</td>
<td>1.4631–1.4641</td>
<td>1.4634</td>
<td>0.0003</td>
</tr>
<tr>
<td>Saponification value (mg KOH/g)</td>
<td>181–191</td>
<td>187</td>
<td>3.18</td>
</tr>
<tr>
<td>Unsaponifiable matter (%)</td>
<td>0.31–0.42</td>
<td>0.38</td>
<td>0.03</td>
</tr>
<tr>
<td>Cloud point (°C)</td>
<td>2.8–5.7</td>
<td>4.4</td>
<td>0.71</td>
</tr>
<tr>
<td>Slip melting point (°C)</td>
<td>12.9–16.6</td>
<td>15.1</td>
<td>0.91</td>
</tr>
<tr>
<td>Iodine value (Wijs)</td>
<td>60.1–67.5</td>
<td>61.9</td>
<td>2.05</td>
</tr>
</tbody>
</table>


Figure 7. Relationship between solid fat content of superolein and iodine value at 2.5°C and 5°C.
Palm stearin is the solid fraction from the fractionation of palm oil. It can be used for obtaining palm mid fractions and also blending with other vegetable oils to obtain functional products, such as margarine fats, shortenings and vanaspati. Palm stearin is a useful natural hardstock for making trans-free fats. It can also be used for soap and other oleochemical products, as well as for animal feed. The specifications for Malaysian palm stearin are given in Standard MS 815:2007 (Table 12).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Observed value (min. to max.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent density, g/ml at 60°C</td>
<td>0.8813 to 0.8844</td>
</tr>
<tr>
<td>Refractive index nD. 40°C</td>
<td>1.4482 to 1.4501</td>
</tr>
<tr>
<td>Saponification value, mg KOH/g oil</td>
<td>193 to 205</td>
</tr>
<tr>
<td>Unsaponifiable matter, %</td>
<td>0.30 to 0.90</td>
</tr>
<tr>
<td>Fatty acid composition (wt% as methyl esters)</td>
<td></td>
</tr>
<tr>
<td>C12:0</td>
<td>0.1 to 0.3</td>
</tr>
<tr>
<td>C14:0</td>
<td>1.1 to 1.7</td>
</tr>
<tr>
<td>C16:0</td>
<td>49.8 to 68.1</td>
</tr>
<tr>
<td>C16:1</td>
<td>&lt;0.05 to 0.1</td>
</tr>
<tr>
<td>C18:0</td>
<td>3.9 to 5.6</td>
</tr>
<tr>
<td>C18:1</td>
<td>20.4 to 34.4</td>
</tr>
<tr>
<td>C18:2</td>
<td>5.0 to 8.9</td>
</tr>
<tr>
<td>C18:3</td>
<td>0.1 to 0.5</td>
</tr>
<tr>
<td>C20:0</td>
<td>0.3 to 0.6</td>
</tr>
<tr>
<td>Iodine value (Wijs)</td>
<td>27.8 to 45.1</td>
</tr>
<tr>
<td>Slip melting point, 50°C</td>
<td>46.6 to 53.8</td>
</tr>
<tr>
<td>Total carotenoids (as β-carotene), mg/kg</td>
<td>300 to 600</td>
</tr>
</tbody>
</table>

Note: The identity characteristics of processed palm stearin do not differ significantly from those of crude palm stearin with the exception of carotenoids which are destroyed during refining.

**Palm Mid Fraction (PMF)**

**General Description**

Palm mid fraction (PMF) is the fraction of palm oil high in POP triglycerides. It is obtained by re-fractionating palm olein or palm stearin. The high POP content provides for a sharp melting profile and a slip melting point of about 35 – 36°C. This allows the oil to be used in confectionery fats. The characteristics of Malaysian PMF are shown in Table 13.

**Table 13. Typical Characteristics of Malaysian Palm Mid Fraction**

<table>
<thead>
<tr>
<th>Iodine Value (Wijs)</th>
<th>34.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty acid composition (wt% as methyl esters)</td>
<td></td>
</tr>
<tr>
<td>C16</td>
<td>55.7</td>
</tr>
<tr>
<td>C18</td>
<td>4.9</td>
</tr>
<tr>
<td>C18:1</td>
<td>34.3</td>
</tr>
<tr>
<td>C18:2</td>
<td>3.5</td>
</tr>
<tr>
<td>Triglyceride Composition* (% by C-No.)</td>
<td></td>
</tr>
<tr>
<td>PPP</td>
<td>2.0</td>
</tr>
<tr>
<td>POP</td>
<td>67.5</td>
</tr>
<tr>
<td>POS</td>
<td>11.2</td>
</tr>
<tr>
<td>Others</td>
<td>19.3</td>
</tr>
</tbody>
</table>

*Note: * P - palmitic acid, O - oleic acid, S - stearic acid.

*Source: PORIM Report PO (34) 81.*

**Palm Kernel Oil**

**General Description**

Palm kernel oil is from the kernel of the oil palm fruit. Its composition and properties differ greatly from palm oil – indeed, it is closer to coconut oil. It is produced by mechanical expression from the kernel. The oil quality is usually good, with free fatty acids generally <2%. It is light yellow in colour, and refined physically to a very light colour for both edible and non-edible use.

The oil is semi-solid at ambient. It is excellent for fractionation into higher-value fractions, such as palm kernel stearin, with good melt down properties. The sharp melting profile indicates the oil suitability for confectionery. Due to its rapid crystallization, it is often used in enrobing or dipping products. The characteristics of Malaysian palm kernel oil are shown in Table 14.
TABLE 14. CHEMICAL CHARACTERISTICS OF MALAYSIAN PALM KERNEL OIL

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Range</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine value (Wijs)</td>
<td>16.2 to 19.2</td>
<td>17.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Saponification value, mg KOH/g oil</td>
<td>243 to 249</td>
<td>245</td>
<td>1.4</td>
</tr>
<tr>
<td>Unsaponifiable matter, %</td>
<td>0.1 to 0.8</td>
<td>0.3</td>
<td>0.16</td>
</tr>
<tr>
<td>Fatty acid composition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(wt %) as methyl esters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C6:0</td>
<td>0.1 to 0.5</td>
<td>0.3</td>
<td>0.07</td>
</tr>
<tr>
<td>C8:0</td>
<td>3.4 to 5.9</td>
<td>4.4</td>
<td>0.47</td>
</tr>
<tr>
<td>C10:0</td>
<td>3.3 to 4.4</td>
<td>3.7</td>
<td>0.24</td>
</tr>
<tr>
<td>C12:0</td>
<td>46.3 to 51.1</td>
<td>48.3</td>
<td>0.94</td>
</tr>
<tr>
<td>C14:0</td>
<td>14.3 to 16.8</td>
<td>15.6</td>
<td>0.33</td>
</tr>
<tr>
<td>C16:0</td>
<td>6.5 to 8.9</td>
<td>7.8</td>
<td>0.36</td>
</tr>
<tr>
<td>C18:0</td>
<td>1.6 to 2.6</td>
<td>2.0</td>
<td>0.19</td>
</tr>
<tr>
<td>C18:1</td>
<td>13.2 to 16.4</td>
<td>15.1</td>
<td>0.74</td>
</tr>
<tr>
<td>C18:2</td>
<td>2.2 to 3.4</td>
<td>2.7</td>
<td>0.22</td>
</tr>
<tr>
<td>Others</td>
<td>Trace to 0.9</td>
<td>0.2</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Source: PORIM Report No. 6 (1986).

Palm kernel olein

General Description

Palm kernel olein is the liquid fraction of palm kernel oil from fractionation. The characteristics of the Malaysian oil are given in Table 15. The solid fat profile shows that the olein is largely melted by about 25ºC, compared to the palm kernel oil which needs 28ºC – 30ºC. The olein can be hydrogenated for a sharper melting profile, enabling its use in coating fats. It is also very useful for margarine fats when combined and interesterified with palm stearin.


<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Range</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine value (Wijs)</td>
<td>20.6 to 25.3</td>
<td>23.0</td>
<td>1.30</td>
</tr>
<tr>
<td>Saponification value, mg KOH/g oil</td>
<td>231 to 244</td>
<td>239</td>
<td>3.70</td>
</tr>
<tr>
<td>Unsaponifiable matter, %</td>
<td>0.26 to 0.72</td>
<td>0.36</td>
<td>0.13</td>
</tr>
<tr>
<td>Fatty acid composition (wt% as methyl esters)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C6:0</td>
<td>0.2 to 0.4</td>
<td>0.2</td>
<td>0.06</td>
</tr>
<tr>
<td>C8:0</td>
<td>3.6 to 5.0</td>
<td>4.3</td>
<td>0.36</td>
</tr>
<tr>
<td>C10:0</td>
<td>3.2 to 4.5</td>
<td>3.6</td>
<td>0.21</td>
</tr>
<tr>
<td>C12:0</td>
<td>42.1 to 46.3</td>
<td>44.7</td>
<td>1.04</td>
</tr>
<tr>
<td>C14:0</td>
<td>12.3 to 15.5</td>
<td>14.0</td>
<td>0.70</td>
</tr>
<tr>
<td>C16:0</td>
<td>7.4 to 10.6</td>
<td>8.3</td>
<td>0.57</td>
</tr>
<tr>
<td>C18:0</td>
<td>1.8 to 2.7</td>
<td>2.3</td>
<td>0.22</td>
</tr>
<tr>
<td>C18:1</td>
<td>14.6 to 21.3</td>
<td>19.2</td>
<td>1.39</td>
</tr>
<tr>
<td>C18:2</td>
<td>2.6 to 3.8</td>
<td>3.3</td>
<td>0.28</td>
</tr>
<tr>
<td>C20:0</td>
<td>0 to 0.2</td>
<td>0.1</td>
<td>0.06</td>
</tr>
<tr>
<td>Triglyceride composition (by C–No. wt%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C26</td>
<td>0 to 0.1</td>
<td>0</td>
<td>0.02</td>
</tr>
<tr>
<td>C28</td>
<td>0.2 to 0.5</td>
<td>0.3</td>
<td>0.04</td>
</tr>
<tr>
<td>C30</td>
<td>1.3 to 1.8</td>
<td>1.6</td>
<td>0.11</td>
</tr>
<tr>
<td>C32</td>
<td>6.6 to 8.4</td>
<td>7.8</td>
<td>0.36</td>
</tr>
<tr>
<td>C34</td>
<td>8.4 to 10.2</td>
<td>9.3</td>
<td>0.33</td>
</tr>
<tr>
<td>C36</td>
<td>16.3 to 19.8</td>
<td>18.3</td>
<td>0.80</td>
</tr>
<tr>
<td>C38</td>
<td>10.1 to 14.0</td>
<td>12.5</td>
<td>0.93</td>
</tr>
<tr>
<td>C40</td>
<td>6.1 to 8.7</td>
<td>7.6</td>
<td>0.55</td>
</tr>
<tr>
<td>C42</td>
<td>8.1 to 9.9</td>
<td>9.3</td>
<td>0.36</td>
</tr>
</tbody>
</table>

**Palm Kernel Stearin**

**General Description**

Palm kernel stearin is the premium product from fractionating palm kernel oil. The solid melting profile enables its use in confectionery fats. The stearin can be used directly or improved by hydrogenation. As with other palm kernel products, it forms eutectic mixtures with pure cocoa butter, and thus can be mixed in cocoa butter confectionery products in small amounts. The characteristics of Malaysian palm kernel stearin are shown in Table 16.
Consumption of palm oil has increased tenfold since 1980 and now stands at around 59.1 million tonnes a year.

### TABLE 16. CHEMICAL CHARACTERISTICS OF MALAYSIAN PALM KERNEL STEARIN

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Range</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine value (Wijs)</td>
<td>5.8 to 8.1</td>
<td>7.0</td>
<td>0.51</td>
</tr>
<tr>
<td>Saponification value, mg KOH/g oil</td>
<td>245 to 254</td>
<td>248</td>
<td>4.08</td>
</tr>
<tr>
<td>Unsaponifiable matter, %</td>
<td>0.22 to 0.60</td>
<td>0.32</td>
<td>0.18</td>
</tr>
<tr>
<td>Fatty acid composition (wt% as methyl esters)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C6:0</td>
<td>0 to 0.1</td>
<td>0.1</td>
<td>0.04</td>
</tr>
<tr>
<td>C8:0</td>
<td>1.5 to 2.3</td>
<td>1.9</td>
<td>0.17</td>
</tr>
<tr>
<td>C10:0</td>
<td>2.5 to 2.9</td>
<td>2.7</td>
<td>0.12</td>
</tr>
<tr>
<td>C12:0</td>
<td>54.8 to 58.2</td>
<td>56.6</td>
<td>0.84</td>
</tr>
<tr>
<td>C14:0</td>
<td>21.1 to 24.1</td>
<td>22.4</td>
<td>0.77</td>
</tr>
<tr>
<td>C16:0</td>
<td>7.2 to 8.6</td>
<td>8.0</td>
<td>0.27</td>
</tr>
<tr>
<td>C18:0</td>
<td>1.3 to 2.2</td>
<td>1.8</td>
<td>0.20</td>
</tr>
<tr>
<td>C18:1</td>
<td>4.6 to 6.8</td>
<td>5.6</td>
<td>0.56</td>
</tr>
<tr>
<td>C18:2</td>
<td>0.6 to 1.1</td>
<td>0.8</td>
<td>0.10</td>
</tr>
<tr>
<td>C20:0</td>
<td>0 to 0.2</td>
<td>0.1</td>
<td>0.06</td>
</tr>
<tr>
<td>C28</td>
<td>0.2 to 0.3</td>
<td>0.1</td>
<td>0.09</td>
</tr>
<tr>
<td>C30</td>
<td>0.4 to 0.9</td>
<td>0.5</td>
<td>0.09</td>
</tr>
<tr>
<td>C32</td>
<td>2.8 to 3.7</td>
<td>3.3</td>
<td>0.16</td>
</tr>
<tr>
<td>Triglyceride composition (by C–No. wt%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C34</td>
<td>6.1 to 6.9</td>
<td>6.5</td>
<td>0.16</td>
</tr>
<tr>
<td>C36</td>
<td>25.9 to 29.2</td>
<td>27.5</td>
<td>0.84</td>
</tr>
<tr>
<td>C38</td>
<td>23.4 to 25.7</td>
<td>24.8</td>
<td>0.43</td>
</tr>
<tr>
<td>C40</td>
<td>14.3 to 16.0</td>
<td>15.2</td>
<td>0.36</td>
</tr>
<tr>
<td>C42</td>
<td>8.1 to 10.1</td>
<td>9.2</td>
<td>0.44</td>
</tr>
<tr>
<td>C44</td>
<td>4.9 to 5.7</td>
<td>5.2</td>
<td>0.21</td>
</tr>
<tr>
<td>C46</td>
<td>2.3 to 3.6</td>
<td>3.0</td>
<td>0.23</td>
</tr>
<tr>
<td>C48</td>
<td>1.1 to 3.4</td>
<td>2.4</td>
<td>0.48</td>
</tr>
<tr>
<td>C50</td>
<td>0.4 to 1.6</td>
<td>0.9</td>
<td>0.25</td>
</tr>
<tr>
<td>C52</td>
<td>0.3 to 1.5</td>
<td>0.7</td>
<td>0.18</td>
</tr>
<tr>
<td>C54</td>
<td>0.5 to 1.1</td>
<td>0.8</td>
<td>0.18</td>
</tr>
</tbody>
</table>

CHAPTER 2:
PALM OIL
NUTRITION
INTRODUCTION

Palm oil is a balanced vegetable oil with almost half saturated content, counterbalanced by monounsaturated and polyunsaturated fatty acids. Palmitic (~44%) is the major saturated fatty acid, with about 39% monounsaturated oleic and about 11% polyunsaturated linoleic. The liquid fraction of palm oil, palm olein, contains higher oleic (~44%) and linoleic (~13%). Palm oil also contains about 1% phytonutrients, such as tocols, carotenoids, sterols, squalene, coenzyme Q10, phospholipids and palm phenolics. Like all other oils and fats, palm oil provides 9 kcal g\(^{-1}\) energy, compared to 4 kcal g\(^{-1}\) for protein and carbohydrate (1 kcal = 4.18 kJ).

Effects of Palm Oil and its Fractions on Blood Lipids

The composition of palm oil, with almost 50% saturated fatty acids, has drawn much criticism, particularly on its effect on cardiovascular health. However, nutritional studies in The Netherlands, Australia, India, China and Malaysia show that the oil does not raise cholesterol levels and behaves more like a monounsaturated oil, like olive.

Numerous human clinical trials have shown that palm olein and olive oil have similar effects on fasting plasma lipids. Two of them were conducted on Malaysian healthy populations, populations, and one on an Australian population (Figure 8).
Both oils also have similar effects on triacylglycerol response after a high fat meal. Our bodies spend most of their time in the post-absorptive state after we eat. The lipid response after a meal predisposes to atherosclerosis, and disease progression to cardiovascular disease. Hence, it is important to note that palm olein is as good as olive oil in triacylglycerol response after a high fat meal.

Palm Oil *Trans*-Free Fat

To prolong the shelf life of liquid vegetable oils, partial hydrogenation is done to convert the polyunsaturated fatty acids to their more stable and solid saturated counterparts. However, this results in the formation of highly deleterious *trans*-fatty acids. Food manufacturers have therefore striven to avoid hydrogenation. One way is to use palm oil *in lieu* of partially hydrogenating other vegetable oils. Palm oil is unique in being naturally semi-saturated and semi-solid, and, therefore, does not require hydrogenation to become more solid, obviating the *trans* problem.

The worldwide quest to eliminate unhealthy *trans* fats should open the door for palm oil as a substitute.

**Sn-2 Hypothesis**

Even though the major fatty acid in palm oil is palmitic, this saturated fatty acid is attached primarily at the two ends of the fat molecule’s backbone - at stereospecific positons 1 and 3 (sn-1 and -3) as shown in Figure 9. In contrast, an animal fat, such as lard, has palmitic in the middle, i.e., at sn-2. Because of the positioning, although the fatty acid compositions...
of palm oil and lard are similar, they have very different triacylglycerol compositions. Palm olein triacylglycerols contain only 7-11% palmitic at sn-2, and approximately 87% of the fatty acids at this position are unsaturated (oleic and linoleic). On the other hand, lard has about 70% palmitic at sn-2. This is illustrated in Figures 10 and 11.

![Figure 9. Structure of a fat molecule.](image-url)
The key point of this hypothesis is that the unsaturated part of palm oil is absorbed intact as a sn-2 monoacylglycerol, while the saturated fatty acids at sn-1 and sn-3 are absorbed as free fatty acids that are then metabolized independently. It is also postulated that the long chain saturated fatty acids, i.e., with >12 carbon atoms, at sn-1 and sn-3, after absorption, are reassembled into new fat molecules (triacylglycerol structures) that are slower to metabolize than...
short and medium chain fatty acids, resulting in lower entry of the metabolites into the bloodstream. This hypothesis may explain why palm oil behaves very differently from other saturated fats, like lard.

The hypothesis is supported by the recent report by the FAO Expert Consultation on Fats and Fatty Acids in Human Nutrition (2010) which states

“There is possible evidence to suggest that total cholesterol (TC) and LDL-C raising effects of palmitic acid are lower for vegetable than animal sources because it is present predominantly in the sn-1 and sn-3 position as opposed to sn-2 position as in animal fats such as lard”.

These observations have helped position palm oil as safe and nutritious for human consumption.

Health Attributes of Palm Phytonutrients

The phytonutrients in palm oil constitute about 1% of its weight. They include tocols (vitamin E, 600 - 1000 parts per million (ppm)), carotenes (500 - 700 ppm), phytosterols (300 - 620 ppm), squalene (250 - 540 ppm), coenzyme Q10 (10 - 80 ppm), palm phenolics (40 - 70 ppm) and phospholipids (20 - 100 ppm). The carotenes and vitamin E are known for their antioxidant as well as anti-inflammatory properties, while the other phytonutrients exhibit numerous other special properties that have promise in the pharmaceuticals, nutraceuticals, and food as well as cosmetics industries (Table 17).

Vitamin E

The vitamin E in palm oil is a mixture of tocopherols (18-22%) and tocochromanols (78-82%). About 70% of the vitamin remains in the bleached, deodorized palm oil, after refining, i.e., 420-700 ppm. Tocopherol is the more powerful antioxidant due to their ability to penetrate tissues with saturated fatty acid layers better.
### TABLE 17. POTENTIAL HEALTH BENEFITS OF PALM PHYTONUTRIENTS

<table>
<thead>
<tr>
<th>Palm Phytonutrient</th>
<th>Potential Health Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin E</td>
<td>- Neuroprotection</td>
</tr>
<tr>
<td></td>
<td>- Anti-cancer</td>
</tr>
<tr>
<td></td>
<td>- Anti-angiogenesis</td>
</tr>
<tr>
<td></td>
<td>- Anti-arterosclerosis</td>
</tr>
<tr>
<td></td>
<td>- Inhibition of cholesterol synthesis</td>
</tr>
<tr>
<td></td>
<td>- Cardioprotection</td>
</tr>
<tr>
<td></td>
<td>- Bone protection</td>
</tr>
<tr>
<td></td>
<td>- Antioxidant</td>
</tr>
<tr>
<td></td>
<td>- Skin protection</td>
</tr>
<tr>
<td></td>
<td>- Anti-inflammatory</td>
</tr>
<tr>
<td>Carotenoids</td>
<td>- Pro-vitamin A activity</td>
</tr>
<tr>
<td></td>
<td>- Prevention of xerophthalmia (night blindness)</td>
</tr>
<tr>
<td></td>
<td>- Anti-cancer</td>
</tr>
<tr>
<td>Palm phenolics</td>
<td>- Anti-oxidant</td>
</tr>
<tr>
<td></td>
<td>- Anti microbial</td>
</tr>
<tr>
<td></td>
<td>- Anti-atherogenic</td>
</tr>
<tr>
<td></td>
<td>- Anti-cancer</td>
</tr>
<tr>
<td></td>
<td>- Anti-diabetic</td>
</tr>
<tr>
<td></td>
<td>- Anti-hypertensive</td>
</tr>
<tr>
<td></td>
<td>- Anti-inflammatory</td>
</tr>
<tr>
<td></td>
<td>- Cardio-protective</td>
</tr>
<tr>
<td></td>
<td>- Protection against age-related muscular degeneration</td>
</tr>
<tr>
<td></td>
<td>- Cognitive enhancement</td>
</tr>
<tr>
<td>Phytosterols</td>
<td>- Hypocholesterolemic</td>
</tr>
<tr>
<td>Squalene</td>
<td>- Metabolic precursor of cholesterol and other steroids</td>
</tr>
<tr>
<td></td>
<td>- Anti-oxidants</td>
</tr>
<tr>
<td></td>
<td>- Strengthen immune system</td>
</tr>
<tr>
<td>Phospholipids</td>
<td>- Synergistic effects with tocols in antioxidant properties</td>
</tr>
<tr>
<td>Co-enzyme Q10</td>
<td>- Anti-oxidative defence mechanism</td>
</tr>
<tr>
<td></td>
<td>- Cardioprotection</td>
</tr>
<tr>
<td></td>
<td>- Anti-cancer</td>
</tr>
</tbody>
</table>

**Carotenoids**

Palm oil is one of the richest sources of carotenoids (500 - 700 ppm). There are 13 compounds in the oil, the major ones being β-carotene, α-carotene, lycopene, phytoene and phytofluene. Carotenoids are the precursors of vitamin A and can prevent night blindness, improve vitamin A status of lactating mothers and their babies, increase serum retinol concentration and combat vitamin A deficiency. In addition to cardiovascular protection, carotenoids also suppress the growth of various cancer cells, such as breast, liver, colon and lung.

Red palm oil is obtained from refining crude palm oil at low temperature which preserves >80% of the carotenoids and vitamin E. The red oil has a special flavour and aroma, and is rich in phytonutrients, like carotenoids (that give the oil its bright red colour), vitamin E, phytosterols and coenzyme Q10. To combat vitamin A deficiency, lactating mothers can supplement their diet with carotenoid-rich red palm oil to promote retinols in their serum and breast milk.
Phytosterols

The major phytosterols in palm oil are β-sitosterol (60%), campasterol (13%), stigmasterol (24%) and cholesterol (3%). The main benefits of phytosterols are lowering cholesterol by inhibiting its absorption and anti-cancer properties.

Squalene

Squalene is a lipophilic antioxidant with the unique characteristic of anchoring to the cell membrane. Daily supplementation of squalene can inhibit cholesterol synthesis and suppress cancer cells.

Coenzyme Q10

Coenzyme Q10, also known as ubiquinone, is claimed to possess 10x the antioxidant property of vitamin E, although the greater abundance of carotenes and vitamin E masks this potency. Other health benefits of coenzyme Q10 include enhanced production of cellular energy, cardio-protection and anti-cancer properties.

Oil Palm Phenolics (OPP)

The oil palm fruit is also a rich source of phenolic compounds. During the milling process, the oil palm phenolics (OPP) enter the aqueous waste stream which is discarded. Pre-clinical trials on OPP have demonstrated numerous biological activities. Caffeoylshikimic acid, a major phenolic in OPP (Table 18), can be hydrolyzed to shikimic acid for pharmaceutical uses.

<table>
<thead>
<tr>
<th>Phenolic compound</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocatechuic acid</td>
<td>600</td>
<td>100</td>
<td>400-800</td>
</tr>
<tr>
<td>-hydroxybenoic acid</td>
<td>7,000</td>
<td>1,000</td>
<td>5,300-8,600</td>
</tr>
<tr>
<td>Caffeoylshikimic acid (Total of three isomers)</td>
<td>10,800</td>
<td>2,400</td>
<td>77,00-15,100</td>
</tr>
<tr>
<td>Total major phenolics</td>
<td>18,400</td>
<td>2,900</td>
<td>13,800-24,300</td>
</tr>
<tr>
<td>Gallic acid equivalents</td>
<td>18,200</td>
<td>1,700</td>
<td>15,700-21,300</td>
</tr>
</tbody>
</table>
Margarine is a water-in-oil emulsion, similar to butter in appearance and composition, and an alternative to it. It was invented in 1869 by Mege Mouriez, using oleo oil from high quality beef fatty tissues. Originally meant to be a cheap substitute for butter, it soon developed into a product in its own right. Margarine offers better spreadability and nutritional qualities, improved baking performance and has a longer shelf life.

Main Types of Margarine

Margarine is made in many types, but the majority are:

1. Table Margarine

   This is often soft and consistent, spreadable at refrigerator temperature and filled in tubs. Hydrogenated fat and a high amount of polyunsaturated vegetable oil are commonly used in conventional soft margarine. With increasing awareness on health, palm stearin of low iodine value is now becoming a popular alternative to hydrogenated fats through direct blending or interesterification.

   Table margarine is formulated to be stable at room temperature. The product is gaining popularity in many tropical countries.
2. All Purpose/Industrial Margarine

Similar in consistency to butter. Extruded and wrapped in small blocks or filled in 250 – 2500 g cans or tubs for table and kitchen use or in 10 – 25 kg cartons as cake margarine for catering and the food industry.

3. Puff Pastry Margarine

This is for catering and industrial use, usually made from vegetable/animal fat blends of higher melting point. It is designed for specific uses, therefore, produced only in small volumes, e.g. puff pastry margarine for pastry products. The oils and fats ingredients are usually vegetable and the product is firm but with high extensibility for excellent working and folding to confer good lift and flakiness to the end product.

Principles of Formulation

The basic principles for formulating margarine are:

• Harder components should be β-prime tending to set the crystallization pattern for the whole;

• A wide range of fatty acid chain lengths is desirable, yielding fat crystals that are β-prime tending;

• Lauric fats confer quick-melting and cool mouth-feel, but reduced spreadability;

• The best guide to desirable characteristics, such as texture, mouth-feel, etc., in any blend is its oil solid fat solid fat content (SFC) profile. However, the correlation is far from perfect and the SFC profile may have to be fine tuned; and
• The chilling, working and tempering conditions employed can produce different textures from the same oil blend.

Palm oil is highly suitable as a major component in margarine because of its following attributes:

• Crystallization in the $\beta$-prime form - there are not many such fats. The main ones are palm oil and its associated products, such as hydrogenated palm oil, palm stearin, etc., hydrogenated cottonseed oil, beef fats and hydrogenated marine oil;

• High palmitic (C16), to reduce excessive C18 in most seed oils;

• 10% linoleic, the major essential fatty acid;

• Natural semi-solid consistency, which can be modified by random interesterification, dispensing with expensive hydrogenation and being free from trans fatty acids; and

• No linolenic, thus, enhancing oxidative stability and minimising flavour reversion of the product.

Examples of margarine oil blends:

i. Table, polyunsaturated (tub), low saturated (stick) and shelf stable (can) margarines

The high polyunsaturated fatty acid formulations by MPOB in Table 19 contain high liquid oil.

The major liquid oils, such as soy, rapeseed and sunflower, can be used interchangeably, but cottonseed and groundnut oils have higher saturated fatty acids and the formula may have to be tweaked.

Palm stearin of various hardness, as well as palm oil, have become the two most popular oils to replace fully or partially hydrogenated oils and are very useful components in trans-free margarine blends. Inclusion of a lauric oil, e.g., palm kernel oil or palm kernel olein, alters the SFC profile, giving improved mouth-feel and faster crystallization.

Palm Oil Fact

Why palm oil is better for health,

Palm fruit oil, naturally semi-solid at room temperature, does not require hydrogenation. It is a good replacement for partially hydrogenated oils for many reasons.
### TABLE 19. OIL BLENDS FOR TABLE, POLYUNSATURATED (TUB), LOW SATURATED (STICK) AND SHELF STABLE (CAN) MARGARINES

<table>
<thead>
<tr>
<th>Product Code</th>
<th>F209</th>
<th>F214</th>
<th>F7</th>
<th>2900</th>
<th>2105</th>
<th>IE</th>
<th>IE</th>
<th>IE</th>
<th>IE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm stearin (IV20)</td>
<td>4</td>
<td>12</td>
<td>5</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm olein (IV58)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid oil</td>
<td>64</td>
<td>80</td>
<td>65</td>
<td>60</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm kernel oil</td>
<td>8</td>
<td>20</td>
<td></td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IE blend of 32/8 palm stearin (IV44)/ palm kernel olein</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PKoO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POS (IV33)</td>
<td>90</td>
<td>20</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapeseed oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
</tr>
</tbody>
</table>

### ii. Trans-Free Margarine

In view of the undesirable nutritional properties of *trans* fatty acids and their mandatory labelling in several countries, many manufacturers are turning to *trans*-free formulations. Palm oil, which is naturally semi-solid, is the preferred alternative.

Various formulations have been developed by MPOB for *trans*-free margarine by either straight blending or interesterification (Tables 19-21). Interesterification increases the amount of palm oil products that can be incorporated and also reduces the SFC of the blend to a level suitable for margarine. The melting properties are correspondingly improved, especially in blends of palm stearin with liquid vegetable oils.

### iii. All-Purpose Domestic and Industrial Cake Margarines (Cans or Pails)

A typical SFC profile for these products for temperate climes (Europe) is 10°C (30%), 15°C (23%), 20°C (17%), 25°C (11%), 30°C (6%) and 35°C (1%). Margarines for tropical countries are normally made much harder, detracting from their organoleptic properties, since the mouth temperature is constant. The following blends (Table 20) have been tested in MPOB and given good results, with SFC values similar or close to those above:
### TABLE 20. ALL-PURPOSE DOMESTIC AND INDUSTRIAL CAKE MARGARINE FORMULATIONS

<table>
<thead>
<tr>
<th></th>
<th>F234</th>
<th>F233</th>
<th>F274</th>
<th>F276</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm stearin (IV 30)</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm oil</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid oil</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm kernel oil</td>
<td>8</td>
<td>10</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Palm olein (IV 58)</td>
<td>67</td>
<td>73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm stearin (IV 33)</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm stearin (IV 36)</td>
<td></td>
<td>22</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Palm stearin (IV 14)</td>
<td></td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

In margarine and shortening formulations, all the common seed oils are quite interchangeable for their effects on the product consistency. The differences only become noticeable at <20°C. The hardness of the product using temperate oils increases in the order soy<rapeseed<sunflower<corn <groundnut<cottonseed.

### iv. Puff Pastry Margarine

In essence, puff pastry is many thin layers of dough separated by fat. It is produced by repeatedly folding and rolling the dough. The fat employed, usually margarine, must be quite firm, yet tough and extensible to withstand the mechanical operation. At the same time, its melting point must not be any higher than necessary as it will then give poor mouth feel.

A good subjective test used by bakers is to roll the dough between the thumb and palm. It should feel firm, yet deform without cracking, and not be sticky. To achieve this, a balance is struck between the solid and liquid oil phases. Hydrogenated oils had been the popular hard stock for this margarine; however, palm stearin of various hardness is now in vogue. Some example trans-free puff pastry formulations are shown in Table 21.

*Puff pastry margarine production in pilot plant*
TABLE 21. PASTRY MARGARINE FORMULATIONS

<table>
<thead>
<tr>
<th></th>
<th>F215 (%)</th>
<th>F133 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm stearin (IV 30)</td>
<td>50</td>
<td>13</td>
</tr>
<tr>
<td>Palm olein (IV 58)</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td>Liquid oil</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Palm stearin (IV 19)</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Palm oil</td>
<td>0</td>
<td>32</td>
</tr>
</tbody>
</table>

v. Interesterified Blends

In recent years, there has been strong pressure from consumer groups in developed countries against chemically altered foods. Hydrogenation reduces unsaturation, but produces geometric and positional isomers (e.g. trans fatty acids), the nutritional status of which is (at least currently) highly undesirable.

Interesterification can be used instead to harden single oils or to alter the melting profiles of blends, without producing any such isomers and without any overall change in the unsaturation. A particularly useful effect is removal of the ‘tail’ from the melting profile of some blends containing appreciable high melting fats, such as palm stearin. Interesterified blends of palm stearin and palm kernel oil or its olein are suitable.

Some interesting examples of such blends, studied by MPOB and recommended for margarine and shortening, are described below.

Interesterified Blends for Margarine and Shortening Formulations

Table 19 gives some example interesterified blends of palm oil products with soft oils as major components in margarine and shortening.

vi. Palm Pourable Margarine

Pourable margarine is an emulsion made by blending a more liquid oil in another oil or fat of higher melting point. After controlled crystallization in a rapid chiller, a fluidized product is obtained, pourable from a bottle. A suitable blend for this margarine is palm oil, palm olein or palm kernel olein as the higher melting component, and soybean or sunflower oil as the liquid oil. Other ingredients needed are emulsifiers, water, salt, skim milk, stabilizers, vitamins, preservatives, antioxidants, colouring and flavouring agents.

The fat blend and oil-soluble ingredients are mixed thoroughly and then chilled rapidly in a scraped surface heat exchanger. Separately, the water-soluble ingredients are mixed in a vessel, and then with the fat phase exiting from the scraped surface heat exchanger into an emulsion, which is fed into a pin-worker for crystal growth. The product coming out of the pin-worker is packed and tempered in a cold
room. Proper combination of the crystallization condition in the heat exchanger and pin-worker will result in a pourable margarine with smooth texture and glossy appearance without oil separation.

Figure 12 shows the SFC profiles of palm pourable margarines A, B, and C. They exhibit narrow ranges of solid fat content between 5°C and 35°C. Figure 13 shows the pouring stability of the products at 18°C. A stable pourable margarine is one which pourability does not change much over storage. Hence, A and B, which pourability changed very little 28 days at 18°C, are superior compared to product C.
SHORTENING

Shortenings were originally substitutes for lard, then in short supply. One of their most important functions is to tenderize, or ‘shorten’, baked products.

Types of Shortenings

Originally, in the United States, shortenings were classified by their formulations, e.g., compound shortenings were mixtures of hard stock with soft oil, and ‘all-hydrogenated’ had higher stability. Gradually, this distinction faded, replaced by the major use intended, e.g., general purpose shortening, high ratio cake shortening, high stability biscuit shortening, etc. In this this pocketbook, they are classified by their consistency, under plastic, pumpable and fluid.

1. Plastic shortenings

These usually possess the following characteristics:

- Consistency similar to lard;
- Normally formulated based on rules similar to those for margarine;
- Prime crystalline structure required for good cake making performance, thus palm oil, palm olein and palm stearin are highly suitable; and
- Often contain an emulsifier for enhanced cake volume.

There are wide variations in the plasticity and melting range according to the geographical region and season of the year, but usually the melting point is 34 – 44°C.

Higher melting shortenings, in theory, provide better support to the cake batter in the early stages of baking, when it begins to rise but still in a very tender stage. However, too high melting affects the mouth-feel and creaming takes longer. Including some emulsifier, such as glycerol monostearate (GMS), improves the cake volume in lean recipes.

In the USA, formulations used to be based on hydrogenated soybean oil, beef fat and cottonseed oil. However, with the mandatory labelling of trans fatty acids in January 2006, manufacturers have avoided hydrogenated fats and palm oil became the preferred solid fat.

In Western Europe (UK, Germany, Netherlands), shortenings are mostly based on palm oil, with manufacturers also avoiding hydrogenated fats. Palm oil, beef fat and fish oil are very desirable functional components because of their prime tendency, but, amongst them, only palm oil is vegetable. This is an important consideration as consumers increasingly avoid animal fats for health reasons.
Interesterified palm olein 100% has produced very good results, either in industry or MPOB baking tests. It is a very simple cost-effective formulation requiring no hydrogenation. The final consistency can be fine-tuned with minor additions of palm stearin or liquid oil.


High ratio cakes are those which incorporate more sugar and liquid than standard cakes. Their lightness, moist texture and sweet taste are liked by consumers. Furthermore, since sugar and water are low-priced ingredients, the cake can be produced inexpensively.

The cakes are made with ‘high ratio shortenings’ - standard shortenings with added monoglycerides. They emulsify and hold more water in the batter and support the tender cake structure during the initial stages of baking.

High ratio shortenings give better results in most cakes on ‘lean’ recipes with reduced fat and egg. There is no best shortening for every cake. The best can only be found by testing individual recipes.

Example Super-Glycerinated Shortening Formulations

Any plastic shortening formulation given earlier  95%
Monoglycerides (GMS)  5%

The monoglycerides must be added after deodorization of the oil because they are volatile and can decompose at high temperature and under vacuum. The quality of the monoglycerides can affect the quality of the shortening. Thus, it should have a low peroxide value and bland taste.
3. Pumpable Shortenings

Pumpable shortenings are used by large bakeries and medium biscuit factories which require more than shortenings in cartons but are not large enough to make their own from oil blends in bulk.

The most common type has the consistency of thick cream and is pumpable at 25 - 30°C, but others are fluid suspensions, emulsions or liquids.

Pumpable shortenings are normally made from β-prime crystallizing fats with high levels of emulsifiers, while pumpable suspension shortenings are from β-prime crystallizing fats without any emulsifier.

Shortening pumpable at 25 – 30°C can be produced by chilling a standard shortening blend prepared the usual way to about 27°C and delivering the blend directly into a vertical tank with a conical bottom and fitted with a paddle-type agitator and means for pressurising with air to 20 psig (1.5 bar). The shortening is kept under constant agitation for 24 – 36 hours until all the latent heat of crystallization is released.

VANASPATI

Vanaspati is the Indian name for hydrogenated vegetable fat used as substitute for butter fat (ghee) in cooking. In some countries, it is also called ‘vegetable ghee’. It is an important food in India and Pakistan, but also popular in the eastern Mediterranean countries where it is known by various names - in Yugoslavia, Greece (voutyros), and in Turkey, Algeria, Morocco (smin). The absence of moisture makes it resistant to microbiological deterioration.

*Traditional briyani rice cooked with vanaspati*
Because vanaspati is a substitute for butter fat which slow crystallization results in a granular texture, this appearance is usually considered a sign of purity and quality. Palm oil, which tends to crystallize in a smooth microcrystalline form highly suitable for margarine and shortenings, is therefore less suitable for grainy vanaspati.

To increase granularity and also the inclusion of palm products (up to 80%), palm oil or, preferably, palm olein, can be selectively hydrogenated to increase the trans content of the blend and ratio of asymmetrical to symmetrical glycerides. However, with the preference for trans-free products, interesterification of palm oil products with palm kernel oil can be used instead to achieve the same desirable attribute as the process also increases asymmetry.

In almost every country where vanaspati is made, its melting point and composition are legislated. For example, in India and Pakistan, the product still has to be hydrogenated (not interestified) to a slip melting point of maximum 41°C and 39°C, respectively.

After hydrogenation, the finished oil is cooled to a light cloudy condition and packed in cans. The stacked cans are allowed to slowly cool further in a cold room to develop the granular texture in a process called tempering.

In recent years, innovative companies have been promoting smoother products which can be produced in a simpler and more cost-effective manner but, of course, still taste the same.

MPOB has studied Indian and Pakistani vanaspati products and Table 22 shows some of their characteristics.

TABLE 22. CHEMICAL CHARACTERISTICS OF GHEE AND VANASPATI

<table>
<thead>
<tr>
<th></th>
<th>GHEE</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cow Typical</td>
<td>Buffalo Typical</td>
<td>Pakistan Mean (n=3)</td>
<td>India Mean (n=3)</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>SMP (ºC)</td>
<td>34.4</td>
<td>29.9</td>
<td>38.1</td>
<td>35.6</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>34.9</td>
<td>28.4</td>
<td>63.5</td>
<td>76.5</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>SFC (%)</td>
<td>10ºC</td>
<td>53.4</td>
<td>51.9</td>
<td>63.6</td>
<td>75.1</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>20ºC</td>
<td>22.6</td>
<td>23.1</td>
<td>40.3</td>
<td>52.6</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>30ºC</td>
<td>7.9</td>
<td>10.3</td>
<td>18.2</td>
<td>20.7</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td>35ºC</td>
<td>3.2</td>
<td>4.0</td>
<td>9.1</td>
<td>6.8</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>40ºC</td>
<td>0</td>
<td>0</td>
<td>4.3</td>
<td>1.3</td>
<td>1.7</td>
</tr>
<tr>
<td>FAC (as wt% methyl esters)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16:0 (palmitic)</td>
<td>27.2</td>
<td>33.7</td>
<td>30.1</td>
<td>14.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturated</td>
<td>68.0</td>
<td>71.7</td>
<td>37.7</td>
<td>23.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsaturated</td>
<td>32.0</td>
<td>28.3</td>
<td>62.2</td>
<td>76.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trans</td>
<td>0.9</td>
<td>1.7</td>
<td>27.0</td>
<td>53.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Vanaspati Formulations (SMP approx. 40°C)

Palm stearin 20%
Palm oil 80%

The formula gives a rather smooth but inexpensive product with no trans fatty acids. For increased granularity, part of the palm oil is replaced with hydrogenated soybean oil, e.g.,

Palm stearin (IV 44) 20%
Palm oil 40%
Hydrogenated soybean oil (32°C) 40%

The top four blends in Table 23, in order of decreasing SMP, with at least 30% palm oil, have given good results. The fifth blend is trans-free, produced by interesterification. It has a more gentle SFC profile but, nevertheless, still gives a good grainy texture.

Thosai, a traditional Indian food pancake. Vanaspati is added as a ghee substitute.
Trans-Free Vanaspati

Palm oil has desirable physical characteristics for vanaspati and does not require hydrogenation. Blending for palm oil products and liquid vegetable oils to the requirements of consistency and melting point of vanaspati is quite feasible. Blending and/or interesterifying palm stearin with soybean, rapeseed and sunflower oils are also suitable for trans-free vanaspati.

Direct blending of 60% palm stearin and 40% liquid vegetable oil produces the most acceptable low melting vanaspati, while 95% palm oil and 5% palm stearin (IV 33) can produce vanaspati of 38°C melting point. The product appears homogenous, and has a soft consistency with no oil separation. In the case of interesterified vanaspati, higher palm stearin (up to 80%) can be incorporated.
BAKERY FATS

Bakery fats are used in bakery products to provide texture and flavour by imparting tenderness, richness and flakiness. There are many types of bakery fats in the market for different applications.
Bread Fats

Although bread can be made without fat by the traditional long fermentation, fat confers a better texture and longer shelf life. The amount of fat used depends on the recipe and preference, e.g. American bread normally contains more fat than British.

One of the best fats for bread is shortening from 100% RBD palm oil. Margarine of 100% palm oil is also excellent. It is a bland ingredient compared to lard and similar fats, and has the advantage of being competitively priced, vegetable and cholesterol-free. A typical formula for white bread by a bakery in Britain is shown in Table 24.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat flour (strong)</td>
<td>100</td>
</tr>
<tr>
<td>Water</td>
<td>60 – 65</td>
</tr>
<tr>
<td>Yeast</td>
<td>3</td>
</tr>
<tr>
<td>Yeast food</td>
<td>0.4</td>
</tr>
<tr>
<td>Salt</td>
<td>2</td>
</tr>
<tr>
<td>Sugar</td>
<td>4</td>
</tr>
<tr>
<td>Mould inhibitor</td>
<td>0.125</td>
</tr>
<tr>
<td>Non-fat dry milk solids</td>
<td>3</td>
</tr>
<tr>
<td>Fat (palm oil)</td>
<td>2</td>
</tr>
<tr>
<td>Emulsifier</td>
<td>0.25</td>
</tr>
</tbody>
</table>

In major western countries, bread is industrially produced in semi- or fully-continuous processes. The flour-gluten dough is prepared by intensive mixing for a few minutes, after adding a small amount of yeast. Here, fat, at about 1% the flour weight, is essential and the British Bakery Industrial Research Association has shown that the critical factor is the solid fat phase at the temperature of the final proof (ca. 37°C). This should be at least 0.022% of the flour weight with as high palmitic content as desirable.

Palm stearin is a highly competitive fat for this purpose, possessing a high SFC profile, high palmitic acid content (>50%) and being cholesterol-free.

Other Yeast-Raised Products

The only difference between various yeast-raised bakery products is their richness as reflected by the relative amounts of sugar, fat, milk and egg used. A comparison of some general formulations is shown in Table 25 (American products).
**TABLE 25. TYPICAL FORMULATIONS FOR BAKERY PRODUCTS**

(IN PARTS BY WEIGHT)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Crackers</th>
<th>Whole Wheat Bread</th>
<th>White Bread</th>
<th>White Rolls (Dinner &amp; Hamburger Rolls, etc)</th>
<th>Sweet Products (Sweet Rolls &amp; Coffee Cakes, etc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Water</td>
<td>56</td>
<td>66</td>
<td>62</td>
<td>64</td>
<td>60</td>
</tr>
<tr>
<td>Yeast</td>
<td>1.5</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Salt</td>
<td>1.75</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2</td>
</tr>
<tr>
<td>Sugar</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Milk (dry skim)</td>
<td>–</td>
<td>–</td>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Shortening</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Eggs (whole)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>10</td>
</tr>
<tr>
<td>Dough conditioner</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Bread Improvers**

Freshly milled flour does not make as good bread as old mature flour which has undergone some oxidation.

Most bread flour on the market can, therefore, be improved by adding ‘bread improvers’, which contain mild oxidizing agents, emulsifiers, etc., to the bread fat.

A suitable formulation is:

- Palm oil (or palm shortening) 48.0%
- Glycerol monostearate 12.5%
- Sugar 29.3%
- Dextrose 10.0%
- Ascorbic acid 0.2%
- Flavouring As needed

Total 100.0%
BISCUIT FATS

Biscuit manufacturers are among the largest users of shortenings. In their production, oils and fats are used for three major purposes:

- Biscuit dough
- Biscuit cream
- Spraying oil after baking

For each use, the requirements of the oil/fat are very different, but palm oil is eminently suitable as a major component in all of them.

1. Biscuit Dough Fats

Biscuit dough varies greatly in its make up, consistency and in the machinery for its processing, and no single fat or blend is best. But for all biscuits, two requirements are essential:

- No tendency for fat bloom
- Long shelf life

Fat bloom on biscuit is not a very well understood phenomenon and one can only be guided by experience. A series of trials in MPOB on shortcake biscuits showed that natural lard gave no bloom, hydrogenated lard with melting point of 38°C only slight bloom, and hydrogenated lard with melting point 44°C severe bloom.

In general, it is common to use blends of two or more oils to have a greater range of fatty acid molecular weights and complexity of the triglycerides, and this approach is followed in making industrial biscuit dough fats. Palm oil has found very successful applications in this field since its high palmitic content is a convenient means for interrupting the sequence of C18 chains in seed oils. Hydrogenated fish oil is also good in this respect, but it is not vegetable and contains trans fatty acids. In the EU, palm oil is now the largest single component of biscuit dough fats, just as palm kernel oil in biscuit cream fats.

Formulations

1. Palm kernel oil or coconut oil 10%
   Palm oil 57%
   Hydrogenated fish oil (or hydrogenated soybean oil (40/42°C) 33%

2. Palm oil 67%
   Hydrogenated fish oil (or hydrogenated soybean oil, 40/42°C) 33%
2. Biscuit Cream Fats

Biscuit cream fats are used in the manufacture of cream for sandwich-type biscuits. A biscuit cream is essentially a blend of fat, sugar, milk solids and flavourings/colour. The fat should have a steep SFC profile so that it is firm at room temperature and melts cleanly and completely in the mouth. Cocoa butter is ideal, but not much used because of its price except in the luxury market. At times, oils of somewhat greater plasticity or higher melting point are preferred because of the climate or price.

In Western countries, top quality biscuit cream is made with lauric CBS, such as palm kernel stearin, while for the mass market, the simplest confectionery fats, hydrogenated palm kernel oil and hydrogenated coconut oil, are used.

Hydrogenated palm kernel oil is particularly popular as it can be made with a wider range of melting points than coconut oil and is also usually more competitively priced. The world production trend is certainly in its favour.

Where even cheaper fats are needed, or in warm countries where higher melting points are required, hydrogenated palm olein is suitable. This fat is also particularly suitable for high quality Bourbon-type biscuit cream, based on cocoa mass, where lauric fats are unsuitable due to the formation of eutectics.
**Suitable Formulations**

Some highly successful formulations from the UK industry are:

1. Hydrogenated palm kernel stearin (32°C or 38°C melting point) 100%
2. Hydrogenated palm kernel oil (32°C, 35°C or 38°C) 100%
   (Melting point according to season, climate and preference)
3. Hydrogenated palm kernel oil (38°C) 50%
   Palm kernel oil 50%
4. Hydrogenated palm kernel oil (35°C) 80%
   Hydrogenated palm kernel oil (42°C) 20%
5. Hydrogenated palm olein (30°C or 42°C) 100%

**Biscuit Spraying Oils**

Certain savoury biscuits are made to a lean cream cracker recipe and then have oil sprayed on after baking to give them a richer taste and an attractive glossy appearance.

The major requirements for the fat are low SFC at 25 – 30°C and very high oxidative stability since the fat is sprayed hot and fully exposed to air on the gluten strands and starch particles of the biscuit shell. However, the fat should have an appreciable solid fat content at 20°C to ensure dry handling.

Lauric fats, such as from palm kernel oil, have the required properties. But blends of palm kernel oil with palm oil products, which are even more economical to use, are also perfectly suitable and widely used.

**Example fat formulations**

1. Palm kernel oil 100%
   - Best Western practice.
2. Palm oil 50% / Palm kernel oil 50%
   - Good Western practice
3. Palm olein 100%
   - For lower cost
4. Hydrogenated palm olein (33/35°C) 100%
   - For hot climates
PEANUT BUTTER

Peanut butter is a popular food paste made mainly from ground roasted peanut. It is eaten as a spread on bread/toast with fruit jelly or jam, but also in savoury sandwiches of all types in place of butter or margarine. It is a very wholesome product containing only two-thirds the fat in butter, is less saturated than margarine and has more protein than prime steak.

Standard of Identity

In the USA, the FDA introduced a standard of identity for peanut butter in 1968, defining it as a food prepared by grinding shelled roasted peanut with the optional addition of not more than 10% other ingredients. Its total oil content must not exceed 55%.

The optional ingredients must perform a useful function, and normally include salt, natural sweeteners, emulsifiers, e.g., lecithin and stabilizers, such as fully hydrogenated vegetable oils, and suitable monoglycerides. Addition of vitamins A, B, C, D or artificial colour, flavour and preservatives is not permitted.

Stabilizers

These are fat-based products added to peanut butter to prevent oil separation and settling of the solids. The crystal form of the stabilizer should be in the β-prime phase. β-crystallizing fats tend to transform gradually into large, coarser crystals, giving a dull surface to the butter and oil separation.

Suitable fats are straight hard palm stearin (IV 30) added with mono- and diglycerides from fully hydrogenated vegetable oils. Palm oil products have the advantage in that they are not required to be declared on the product label and palm stearin is gaining particular favour since it is fully natural, and usually the most competitively priced.

Formulations

With the increasing health consciousness of EU consumers, the use of palm oil products as stabilizers in peanut butter has become virtually standard practice. Typical peanut butter formulations are:

1. Top quality
   Roasted peanut 96%
   Palm stearin (IV 30) 2%
   Salt 2%
2. Slightly cheaper version
Roasted peanut 90%
Sugar 7%
Palm stearin (IV 30) 2%
Salt 1%

3. Slightly less sweet product
Roasted peanut 90%
Corn syrup solids 6.5%
Palm stearin (IV 30) or hydrogenated palm oil (IV 5 – 10) 2%
Salt 1.5%

In all recipes, the final total oil content should be adjusted to 55% max, by addition or removal of peanut oil.

FLOUR CONFECTIONERY

Flour confectionery is based on flour and sugar, with normally much fat. The main types are cakes, including gateaux and pastries. For these products, the best fats are butter for flavour and all-vegetable, purpose-made margarine and shortening for optimum texture and appearance.

Cakes/Gateaux

Cakes are produced worldwide. The current trend is for industrial production for lower cost and greater convenience. Some example cake recipes are shown in Table 26.
### TABLE 26. TYPICAL FORMULAE FOR MAJOR CAKE TYPES (WT %)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Pound Cake</th>
<th>Ordinary Yellow Cake</th>
<th>High Ratio Yellow Cake</th>
<th>Ordinary White Cake</th>
<th>High Ratio White Cake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Sugar</td>
<td>100</td>
<td>85</td>
<td>132</td>
<td>100</td>
<td>140</td>
</tr>
<tr>
<td>Fat</td>
<td>80</td>
<td>45</td>
<td>50</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Eggs</td>
<td>100</td>
<td>50</td>
<td>50</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>Milk</td>
<td>20</td>
<td>50</td>
<td>100</td>
<td>60</td>
<td>95</td>
</tr>
<tr>
<td>Baking powder</td>
<td>–</td>
<td>2.3</td>
<td>5.8</td>
<td>2.3</td>
<td>3.8</td>
</tr>
<tr>
<td>Salt</td>
<td>2.8</td>
<td>2.0</td>
<td>3.6</td>
<td>2.3</td>
<td>3.8</td>
</tr>
<tr>
<td>Flavour</td>
<td>2.0</td>
<td>1.3</td>
<td>2.3</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Total Wt</td>
<td>405</td>
<td>336</td>
<td>444</td>
<td>388</td>
<td>477</td>
</tr>
</tbody>
</table>

### Fat Requirements

Cake is distinguished by a combination of extreme sweetness and a highly developed cellular structure. Therefore, the dough is thinner and more fluid than for other baked goods. In order for this dough to rise and assume the desired texture during baking, its structural requirements are critical. Consequently, the requirements for cake fat are much more exacting than those for most other products. The industry requires two essential attributes:

- Confer good cake volume and small uniform cell structure.
- Uniform and consistent performance.

Oxidative stability is not a major concern since cakes are eaten fresh. But all-vegetable is a marketing advantage, especially in western countries.

The recommended fats are:

- All vegetable cake margarines or shortenings (see formulations under relevant sections).
- As above, mixed with butter.
Short pastry is essentially flour, fat and a little salt and water. Some recipes may also contain some sugar and egg. The fat is usually around 40%.

This pastry is required to have a tender and crumbly texture. Generous fat in the dough not only makes the pastry tenderer but also prevents it from becoming soggy from absorption of wet ingredients possibly present.

The requirements for a good pastry fat are plasticity and high shortening value. Shortening value is the ability of the fat to aid tenderising in baked products. The abilities to cream and emulsify and high stability to oxidation are not important.

**Recommended Fats**

The original fat used for pastry was lard, which has high shortening value and a flavour liked by some. But most consumers now prefer bland fats, and lard has become expensive. Both 100% palm oil and soft shortening based on palm oil give equally good results and are nutritionally desirable. Some palm olein can be added to the formulation for extra shortness.

**Puff Pastry and Danish pastry**

Puff pastry and Danish pastry are extremely popular bakery products nowadays. The distribution of fat in the dough is attained not by mixing but by rolling it in.
Normally, there is little fat in the dough but the fat rolled in is often more than in the dough. The finished products, therefore, have very high fat content.

**Typical Puff Pastry Recipe (kg)**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread flour</td>
<td>100</td>
</tr>
<tr>
<td>*Cake margarine or butter</td>
<td>12</td>
</tr>
<tr>
<td>Pastry margarine</td>
<td>88</td>
</tr>
<tr>
<td>Water</td>
<td>55</td>
</tr>
<tr>
<td>Salt</td>
<td>1</td>
</tr>
<tr>
<td>Liquid egg colour</td>
<td>As needed</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>256</td>
</tr>
</tbody>
</table>

*The cake margarine or butter is used for making the dough and the pastry margarine for rolling in.*

In preparing these products, the dough, which may or may not be fermented, is first rolled into a sheet, covered with the fat, and then folded in three to form three layers of dough separated by two layers of fat. The folding and rolling is repeated five or six times so that a large number of layers are formed (e.g. five foldings, or or half turns, produce 243 layers).

During baking, the expansion of air and steam separates the layers and produces the characteristic flaky texture.

From the above description, puff pastry products require a hard yet tough and extensible fat, able to withstand repeated rolling into very thin layers. Special pastry margarines and shortenings are made for this purpose, but the former are more popular. A useful empirical way for assessing them is to knead in the palm and then stretch with the thumb. They should feel tough, waxy and not friable or gritty.

Although it is easier to obtain a tough product by a formulation of high melting point, this should not be too high, for the mouth-feel of the final product. It is, therefore, good practice to use the lowest melting point that gives the required performance.

**Recommended Fats**

- All vegetable palm puff pastry margarines are preferred (see under margarine).
- Alternatively, cake margarines can be used if kept cool in a refrigerator.
- For better flavour, combinations of butter and margarine can be used in the pastry.
Convenience foods are now big business in developed countries. One of these is dry, packaged mixes containing flour, sugar, milk solids, shortening, aeration agents and flavours, which only need mixing with water or milk and eggs to yield a batter ready for baking. Shortenings for this application should have a highly stable and firm consistency, and are normally super-glycerinated. Margarines cannot be used because their moisture content would cause margarine deterioration.

Palm oil and fully hydrogenated palm oil or fully hydrogenated palm olein or low iodine value palm stearin are very suitable, being vegetable and highly stable. The use of palm oil is limited as the final products require fats with high melting points. However, the current fractionation technology can produce palm stearin of low iodine value. Thus, as alternative to hydrogenated fats with SMP 50°C, palm stearin of IV 20 is suitable, while fats with melting point 36°C can conveniently be replaced by palm oil.

Examples:

**Shortening for dry cake**

1. Hydrogenated fish oil (50°C), or palm stearin of IV 20 4.8%
   Hydrogenated soybean oil (36°C), or palm oil 43.3%
   Hydrogenated palm oil (38°C), or palm oil 48.1%
   Distilled monoglycerides 3.8%

**Shortening formulations for dry pastry mixes**

1. Palm oil 85%
   Palm stearin (IV 33), or 15%

2. Palm oil 100%

**Typical formulations for short pastry mix**

Flour (soft) 100 kg
Shortening 53 kg
Castor sugar 19 kg
Salt 1 kg
**Total** 173 kg
ROLLED FONDANT

In culinary art, the word “fondant” refers to sugar-based pastes used in preparing and decorating cake, pastry and confectionery. Rolled fondant is almost like a very sweet dough. The type and amount of fat in it may influence the quality characteristics of the final product. The acceptability of a fondant is the combined function of sucrose and fat levels.

Besides butter, hydrogenated vegetable oils have been used and there are some already commercially available. Since palm oil is semi-solid, non-hydrogenated palm products are better alternatives to hydrogenated fats. The fat contributes to softer and more flexible fondant. Non-hydrogenated palm shortening at 8.5% w/w suffices for fondant.
These are oils used in catering and in the home for general food preparation. The quality requirements are a compromise between the clarity expected of table oils and the oxidative resistance of frying oils. Price, however, is the greatest importance.

In the prosperous European countries, groundnut, winterized cottonseed and sunflower oils fit the purpose well and are highly regarded, but often too expensive. In the USA, partially hydrogenated winterized soybean oil with <2% linolenic is the most common, while in warm tropical countries, palm olein with a cloud point of maximum 10°C and of good colour is the popular choice.

To take advantage of the high stability of palm olein and prolong the time it remains clear, blending with other liquid seed oils, including olive, is recommended where permitted. For example:

1. For tropical climes, and all uses,
   Palm olein (IV 58) 100%

2. For temperate countries, catering use,
   Palm olein (IV 58) 50%–75%
   Seed oil 50%–25%

3. For temperate countries, domestic use,
   Palm olein (IV 58) 25%–50%
   Seed oil 75%–50%

Super Olein

Low cloud point olein, or super olein, can be made even more resistant to clouding if blended with more liquid oil. Super olein has IV of 60 or above and maximum cloud point of 6°C. In practical terms, under storage at 15 – 20°C, it is approximately equivalent to a blend of 50/50 standard palm olein/liquid oil. In the EU, blends of super olein with other vegetable oils have been introduced. In the warmer countries of West Asia and South East Asia, similar blends based on standard palm olein have been on the market for many years.

NoveLin™

As normal palm olein clouds at about 10°C (the clouding does not affect the quality or palatability of the olein), NoveLin™ has been developed by MPOB as a blend of palm olein and vegetable oil which does not cloud at the ambient of temperate countries, thus, enabling its use as cooking and salad oils, and for frying, etc.
SPRAY OIL

Palm spray oil in pressurized container is a non-stick medium for frying, especially for omelette, pancake, spaghetti, bread, macaroni, rice and instant noodles. The oil can also be used for instant cooking and roasting - sprayed on roasting chicken, barbecue meat, ‘satay’ and even used as salad dressing. The major ingredient is palm olein.

FRYING OILS AND FATS

Frying is probably the most widely used cooking process in industry. It is quick, easily adaptable to mass production and produces tasty products of attractive appearance and good keepability. The function of oil or fat in frying is as a heat transfer medium and source of flavour and nutrition, since some of it is absorbed by the fried food.

In shallow frying at home or restaurants, where the fat is not re-used, any fat will do, even polyunsaturated oils, although most of them produce some stench.

In commercial and industrial establishments, deep frying is the norm. The following are important attributes of deep frying oils:

• High resistance to oxidation and gum formation.
• Low free fatty acid (FFA) rise and smoke point.
• Low rate of foaming.
• Low rate of darkening.
• Low melting point (except for special purpose).
• Nutritionally good fatty acid composition.
The frying life is very important in determining the quality and cost of the oil. In restaurants, visual impression and subjective assessment of parameters, like the oil colour and amount of smoke produced, are relied on, while in industry, the FFA test is by far the most common with the end point fixed according to the product. Other useful quick tests are the changes in iodine value, dielectric constant and viscosity.

The levels of oxidized fatty acids (recommended maximum 1%) and polar compounds (maximum 25%) are more meaningful parameters, with the latter now enforced in several Western European countries, such as France, Germany and Switzerland. However, the tests for them are elaborate, and thus have not found much favour in industry.

Palm oil is the most widely used industrial frying medium because it does not produce room stench due to the absence of linolenic, has high resistance to oxidation due to its low unsaturation, does not polymerize to gums, has a melting point below mouth temperature and a nutritionally good fatty acid composition which is 50% unsaturated and no trans or iso-acids.

Palm oil is even better for certain purposes, e.g., potato crisps or chips, and other fried snacks. These products absorb a large amount of the fat, ca. 40% of final product weight, and are eaten cold. Palm olein with its lower melting point of about 22°C gives a better mouth feel, better product gloss and, being fluid, allows immediate circulation of the oil at start up after overnight and weekend close. This is often an overriding advantage over solid fats in large operations.

Frying (nuggets)
Palm oil fried products have a tendency to darken faster than products fried with some other oils. This is due to the trace amounts of certain natural phenolics, but the effect is not great and does not indicate oxidation of the oil.

**Thermal Properties**

The smoke point is an important parameter in assessing the quality of used oils in restaurants, while the flash point, which is related to it, is an important safety factor. Both are functions of the molecular weight and, especially, the fatty acid content of the oil. For oils containing mainly C16 and C18 fatty acids, the average smoke points and flash points obtained by MPOB are shown in Table 27.

<table>
<thead>
<tr>
<th>FFA Content (%)</th>
<th>Smoke Point (°C)</th>
<th>Flash Point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>240</td>
<td>330</td>
</tr>
<tr>
<td>0.02</td>
<td>227</td>
<td>328</td>
</tr>
<tr>
<td>0.03</td>
<td>220</td>
<td>327</td>
</tr>
<tr>
<td>0.05</td>
<td>210</td>
<td>325</td>
</tr>
<tr>
<td>0.1</td>
<td>200</td>
<td>320</td>
</tr>
<tr>
<td>0.5</td>
<td>170</td>
<td>305</td>
</tr>
<tr>
<td>1.0</td>
<td>155</td>
<td>300</td>
</tr>
<tr>
<td>2.0</td>
<td>145</td>
<td>290</td>
</tr>
<tr>
<td>5.0</td>
<td>130</td>
<td>265</td>
</tr>
<tr>
<td>10.0</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td>50.0</td>
<td>100</td>
<td>205</td>
</tr>
<tr>
<td>100.0</td>
<td>95</td>
<td>190</td>
</tr>
</tbody>
</table>

**Chips (French Fries)**

Par-fried potato chips, or French fries, are chips cooked in hot water or steam, then sealed by immersing briefly in hot oil. The chips are packed in containers and sold either chilled or frozen. The consumer only has to fry them in hot oil for a few minutes before serving.

They offer great advantages in speed and convenience to working wives and restaurants where labour for dreary vegetable preparation is often difficult to get, especially in developed countries. Accordingly, this industry has expanded very rapidly.

Recently, fully fried chips have appeared with only the need to warm up in a conventional or microwave oven before serving. Their main advantages are even greater convenience and safety in their preparation. Since no hot oil is used, even children can prepare them. The fat content for these products is claimed to be as low as 5%.
Oil Requirements

Due to the long turn-over period and small oil take-up, only oils of low foaming tendency and good oxidative stability are suitable. In addition, the conditions in most freezing plants require oils of relatively high melting point of 42–46°C.

**Recommended oils for pre-frying:**

**Frozen chips**

- Palm stearin (IV 33), melting point 42/44°C 100%
- Blend of hydrogenated palm oil (melting point 44/46°C) and palm oil 75%/25%
POTATO CRISPS

Potato crisps, also known in the USA as chips, are thinly sliced potato about 1 mm thick, fried in oil or fat with salt and other flavourings added to taste. In both Europe and the USA, this product makes up the bulk of a huge snacks market.

Crisps have a highly porous structure and fat content of 35 – 40%. The fat in the cooker is expected to remain in satisfactory condition simply by topping up, and large companies require a product shelf life of up to six months to allow for storage and distribution. Accordingly, the requirements imposed on the fat are onerous and only ‘heavy duty’ frying oils are suitable.

The design of the fryer and the way it is operated can have a profound effect on the rate of oil deterioration. The most critical requirements are that the oil turnover time, i.e. the hours to use up the amount of oil equal to the capacity of the fryer, should be as short as possible, minimum exposure to air, no stoppages and continuous removal of frying debris.

The FFA test is most commonly used to assess the quality of the oil in the fryer because, in spite of its theoretical limitations, it is very simple to carry out and the extent to which the oils has been used correlates well with the severity of the frying conditions employed. An FFA limit of 0.2 – 0.4% (as oleic) is usual for crisps and similar goods. Undoubtedly, the most suitable oil is palm olein because it has the following properties:

• A desirable melting point at room temperature (22°C).
• High oxidative stability – low diunsaturated acids (~11%), no triunsaturates.
• Contains natural antioxidants (tocopherols and tocotrienols).
• No room stench.
• Usually competitively priced.
For companies having heated storage tanks, palm oil can be used for an even lower price. Except for its higher melting point of about 36°C, its performance is equal to that of palm olein.

Groundnut and cottonseed oils are also excellent for industrial frying, but in recent years have become too expensive. However, where cost consideration allows, a blend of 75%/25% CSO/PO has enhanced stability and good fluidity over straight cottonseed oil.

Soybean and rapeseed oils are not suitable for industrial frying despite being subsidised in certain countries. A 50%/50% blend with palm oil has been used with fairly acceptable results.

**EXPANDED AND EXTRUDED SNACKS**

These are starch-based products which are increasingly popular in recent years. Essentially potato crisps, these expanded snacks and nuts have the same requirements for their oils, viz., high stability, no gummy deposits in the cooker, good flavour both during frying and after storage.

Palm olein is the standard oil used and, in replacing high cost oils, such as cottonseed or hydrogenated soybean, offers substantial savings. Palm oil is equally suitable in performance and gives even better savings. It has the advantage of retaining surface salt better. For extruded snacks, the requirements on the oil are much less severe since there is no prolonged exposure to high temperature.

Nevertheless, it is usually uneconomic or impractical to use different oils for different products in snack factories, and palm olein is generally the preferred oil overall.
NUTS (FRIED)

This is a very nutritious snack, popular throughout the world. There are two main types - fried and dry roasted - the former by far the greater volume. All nuts have naturally high oil contents, and in frying take up very little more from the cooker. Rather, oil, proteinaceous and other matter from the nuts leak into the frying oil, causing its fairly rapid deterioration, high FFA and foaming. FFA of 2 – 4% after frying is usual, and the point of oil rejection depends on the product shelf life required. In any case, the oil has to be rejected when dense foam threatens to overflow the cooker.

For these reasons, only the best heavy duty frying oils are used. Palm olein is excellent for frying nuts as it is for crisps and for the same reasons mentioned earlier (see section on potato crisps).

For fried nuts, a glossy appearance is a major requirement. Palm olein, being virtually 100% liquid at the usual room temperature (20ºC), confers full gloss. Palm oil is equally good in all other respects except gloss, but it holds the salt a little better.

In nut frying, one of the most serious problem is oil foaming and the usual cause is the quality and age of the nuts, not the oil. Addition of antioxidants, where permitted, especially at 2 – 3 mg/kg methyl silicone or silicone oil, as anti-foaming agent is advisable.

With regard to antioxidants, BHA and BHT are about equally effective. A 1:1 blend of the two shows a certain amount of synergism, but TBHQ is by far the most effective in palm oil product. In all cases, up to 100 ppm citric acid are recommended as metal chelating agent to enhance the effect of other antioxidants.

DOUGHNUT

Doughnut, crullers and similar food products are a class of bakery goods not baked, but deep fried in fat. The products use very little fat in their dough but, during frying, absorb much of it.

Ideally, the fat should:

• Maintain good flavour during frying.
• Confer long shelf life - some doughnuts are packed and sold much later.
• Have appropriate crystallization behaviour since the fat has to be firm enough to hold the sugar dusted on without soaking it and yet be soft enough to give a bright surface and good mouth feel.
Instant noodles

INSTANT NOODLES

These are noodles made from wheat flour and extruded, then cooked in water, drained and passed through a frying kettle to finish. For consumption, they only need brief simmering (one to two minutes) in water or chicken stock.

Their advantages in taste, convenience and low cost have led to a rapid growth, especially in East Asia. Similar products or variations on the theme are expanding in Western countries.

Preferred oils are:

• In Western Europe, palm oil and palm olein have become virtually the standard oils used.

• In Asia, especially Japan, China and Korea, lard and beef fat were formerly used because of availability and low prices, but they suffer rapid oxidation, flavour and nutritional problems, and palm oil and palm olein are now gaining ground fast - used either on their own or added to the animal fats to improve their quality.

In large scale industrial production, where extra shelf life is required, soft palm stearin of IV 42 – 48 can be used. Addition of permitted antioxidants, such as BHA, BHT or TBHQ, is beneficial for improving stability.
Cocoa Butter Equivalent

Cocoa butter equivalents (CBE) are vegetable fats with symmetrical 2-oleochemical triglycerides of C16 and C18 fatty acids, similar to those in cocoa butter. They should be compatible with cocoa butter in the proportions normally used in chocolate. A quantitative definition proposed by European Commission (EC) is:

**EC Definition of CBE**

Vegetable fats which comply with the following criteria:

- Level of triglycerides of types SOS* $\geq 65\%$
- Fraction of the 2-position of triglycerides occupied by unsaturated fatty acid $\geq 85\%$
- Total unsaturated fatty acids $\leq 45\%$
- Unsaturated fatty acids with two double bonds $\leq 5\%$
- Lauric acid content $\leq 1\%$
- *Trans* fatty acid content $\leq 2\%$

(*S = saturated fatty acids, O = oleic acid)

In the manufacture of chocolate, all CBE requires tempering, just like cocoa butter.

**The major triglycerides in cocoa butter are:**

<table>
<thead>
<tr>
<th>Triglyceride</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>POP*</td>
<td>17%</td>
</tr>
<tr>
<td>POS*</td>
<td>37%</td>
</tr>
<tr>
<td>SOS</td>
<td>23%</td>
</tr>
<tr>
<td>Others</td>
<td>23%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

(*P = palmitic, O = oleic, S = stearic acid)

PMF is the best known source of POP and all the current commercial CBE fats are usually based on PMF as their major component. Table 28 gives the properties of Malaysian CBE and PMF compared with cocoa butter.
**TABLE 28. TYPICAL CHARACTERISTICS OF MALAYSIAN CBE FATS, PALM MID FRACTION AND COCOA BUTTER**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>CBE Formula 3100</th>
<th>CBE Formula 3200</th>
<th>Palm Mid Fraction</th>
<th>Cocoa Butter (M’sian)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFA (% as oleic)</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>IV (Wij’s)</td>
<td>32–38</td>
<td>32–38</td>
<td>32–36</td>
<td>35</td>
</tr>
<tr>
<td>SMP, °C</td>
<td>33–36</td>
<td>33–36</td>
<td>32–35</td>
<td>33</td>
</tr>
<tr>
<td>SFC, % (stabilized NMR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20°C</td>
<td>Min 72</td>
<td>Min 72</td>
<td>Min 72</td>
<td>84</td>
</tr>
<tr>
<td>30°C</td>
<td>Min 40</td>
<td>Min 50</td>
<td>Min 32</td>
<td>54</td>
</tr>
<tr>
<td>35°C</td>
<td>Max 6</td>
<td>Max 10</td>
<td>Max 6</td>
<td>3.5</td>
</tr>
</tbody>
</table>

*Source: Manufacturers’ brochures.*

In the USA and some EU countries, only cocoa butter and milk fat are permitted in chocolate. But in most other countries, including UK and Ireland, five percent CBE is allowed to replace cocoa butter. When made with good quality CBE, it is impossible to distinguish the chocolate organoleptically or by processing behaviour from that made with 100% cocoa butter.

**Supercoating**

Another chocolate-type product of high quality but very difficult to distinguish from genuine chocolate is made to a chocolate recipe but with CBE replacing all the cocoa butter (Table 29). The product is supercoating which needs tempering exactly as in genuine chocolate.

**TABLE 29. TYPICAL, HIGH QUALITY RECIPES FOR CHOCOLATE AND SUPERCOATING**

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Milk Chocolate (USA) (g/100g)</th>
<th>Milk Chocolate (UK) (g/100g)</th>
<th>Milk Supercoating (g/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa mass (54%)</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Full cream milk powder</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Added cocoa butter</td>
<td>25</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>CBE</td>
<td>–</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Sugar</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

*Note: Fat content is typically 35% for all.*
Cocoa Butter Substitutes

Cocoa butter substitutes (CBS) are fats which have similar physical properties to cocoa butter but different triglyceride composition. Products made with CBS are called substitute chocolate, or coatings, and they do not need tempering.

CBS fats can be conveniently classified into two groups:

- Lauric CBS, relying on high levels of lauric acid; and
- Non-lauric CBS relying on high levels of trans isomers.

Lauric CBS

Lauric CBS owes its sharp melting property to high levels of the shorter chain saturated fatty acids, mostly lauric. It is the least compatible with cocoa butter and in coating recipes all the cocoa mass must be replaced by cocoa powder. Milk fat should also be low and normally skim powder is used. The ideal lauric CBS are those made from fractionated PKO, i.e. hydrogenated PKO (HPKO) and hydrogenated PK stearin (HPKS). Typical characteristics of this group are shown in Table 30:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>HPKO</th>
<th>HPK Stearin</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFA, % max (as lauric)</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>IV max</td>
<td>8</td>
<td>1.0</td>
</tr>
<tr>
<td>SMP, °C</td>
<td>36–39</td>
<td>32–36</td>
</tr>
<tr>
<td>SFC, % (NMR)</td>
<td>65</td>
<td>90</td>
</tr>
<tr>
<td>20°C</td>
<td>17</td>
<td>39</td>
</tr>
<tr>
<td>35°C</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>40°C</td>
<td>4</td>
<td>nil</td>
</tr>
</tbody>
</table>

Hydrogenated PKO (HPKO) made to melting points of 30 – 40°C as required by the climate and use. Sometimes, the HPKO is interesterified to make it melt in a sharper range but this is not very common in Europe.

Hydrogenated PK stearin (HPKS), either partially or fully hydrogenated, and with or without emulsifiers. This is the highest grade CBS. It is hard, yet melts sharply below body temperature with good mouth-feel. It also contracts very well in moulding and is therefore particularly suitable for Easter egg production.

A typical high quality coating formulation (milk type) using lauric CBS is:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa powder (10-12% cocoa butter content)</td>
<td>5%</td>
</tr>
<tr>
<td>Skim milk powder</td>
<td>15%</td>
</tr>
<tr>
<td>CBS</td>
<td>35%</td>
</tr>
<tr>
<td>Sugar</td>
<td>45%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
Non-Lauric CBS

Sometimes called cocoa butter extenders (CBEx or CBX), or cocoa butter replacers (CBR), these fats are based on C16 and C18 fatty acids, the same as in cocoa butter (but not with the same triglycerides). They are therefore partially compatible with cocoa butter and owe their sharp melting properties to high levels of trans fatty acids, especially elaidic (C18:1 trans).

Coatings made with them have long shelf life against bloom and are relatively resistant to developing a soapy flavour. Organoleptically, they are not as good as lauric CBS but in the right applications, their other advantages may make them preferable.

Confectionery made with CBS

When used alone, they do not need tempering, but normally are used with some cocoa butter, and good tempering is needed to stabilize the cocoa butter part.

Formulations

- 100% super olein
- Palm olein/soybean oil or cottonseed oil blends

The above are hydrogenated under the highest possible trans promoting conditions to SMP 37°C/39°C. Some products are fractionated after the hydrogenation to remove the highest melting triglycerides, i.e., the tail in the SFC profile.

Chocolate Pastel

Chocolate is normally formulated with cocoa butter, cocoa liquor and sugar. In milk chocolate, milk fat is added.

However, in chocolate pastel, cocoa is omitted completely and the product relies mainly on the milk fat for its flavour. Chocolate pastel is prepared by the same process as normal chocolate. The fats are mixed with full cream milk powder, skim milk powder and sugar. The mixture is refined through a triple roll mill and conched. The chocolate is then tempered, moulded, cooled and packed in a box.
Chocolate Spreads

Chocolate spreads are sweet and very popular among children, especially when applied on bread. The spreads contain fine solids dispersed in a continuous phase which can be an oil emulsion or water-in-oil emulsion if it contains <40% fat. Different varieties of chocolate spreads, such as pure chocolate spread, chocolate milk spread and chocolate nut paste spread, are available.

The principal ingredients of chocolate spread are fats and oils, cocoa powder, milk powder, sugars (sucrose, fructose and dextrose) and emulsifiers. In addition, flavours, such as hazelnut or peanut paste, may be incorporated. The characteristics of the fat, which is the continuous phase, greatly influence the properties of the final product. Fats shorten the structure. In choosing the fat, it is important to consider its rate of crystallisation at the application temperature, and oxidation and flavour stability.

The typical fats used in chocolate spread have a melting range of 32 – 38°C. They may be palm oil fractions and other liquid vegetable oils. The fat should enable formation of a semi-solid product at 5 – 10°C. Using a modified fat will avoid post-hardening of the product during storage.

In low-fat chocolate spread, where water is an ingredient, it is essential to add a preservative to impart resistance against microbiological deterioration. Protein material is necessary for nutritional reasons, and it also contributes to flavour as well as desirable physical properties of the products. Incorporation of skim milk powder can increase the product viscosity, preventing oil separation.

The use of a suitable fat in chocolate spread will enhance its appearance, stability against rancidity, minimise oil separation and post-hardening, and promote quick-melt in the mouth, resulting in excellent flavour release.
The product is soft and spreadable over a wide range of temperature, from refrigeration to room temperature. It should be smooth, creamy and possess good taste. A narrow distribution of particle size of the fat in the spread as a result of efficient processing will also produce a stable product against heat and biological deterioration.

**RED OLEIN DRINK**

Functional beverages is a generic term for drinks containing active ingredients linked to health benefits. Commercially available functional beverages come with claims ranging from increased mental alertness, energy, protection against various degenerative diseases to weight management.

*Beta* carotene-rich red olein drink is a functional beverage formulated using a blend of red palm olein and other vegetable oils to meet the healthy fatty acid combination of saturated, monounsaturated and polyunsaturated in the ratio 1:1:1, as recommended by the American Heart Association. In addition, the drink is also a source of Vitamin A because the olein contains carotenoids, a vitamin A precursor.

Active ingredients in functional beverages are generally water-soluble so they can be easily incorporated in the water. Enriching the drinks with oil soluble ingredients is a challenge, but one already overcome in the production of red olein drink, which addresses the need for consumption of vitamin A and an oil with the desired 1:1:1 fatty acid ratio.

**Product Properties**

Red olein drink, is an oil blend with omega-3 and red palm olein, a food conditioner, emulsifier and flavouring agent. The ingredients are dispersed in water to produce an emulsion of the desired flavour, viscosity and taste. The drink is formulated to be slightly different in its physical properties from commercial milk products, which are also emulsion drinks.

**Production Potential**

Red olein drink is a simple product but one which requires the appropriate technology to produce. With increasing consumer awareness of a healthy lifestyle and food, the product has good market potential.
SUGAR CONFECTIONERY

This product is essentially sugar glucose and fat boiled together. The best known examples are toffee and caramel. Fats are essential ingredients in all boiled sugar confectionery to provide the texture and richness.

The traditional fats used are cocoa butter and dairy butter, both very expensive, especially the former. Now, these confections never contain cocoa butter, except the most luxurious forms.

A typical formulation for toffee is:

<table>
<thead>
<tr>
<th>Toffee Recipe (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>White sugar</td>
<td>27</td>
</tr>
<tr>
<td>Glucose (42 E)</td>
<td>27</td>
</tr>
<tr>
<td>Full cream sweetened condensed milk</td>
<td>27</td>
</tr>
<tr>
<td>Fat</td>
<td>16.5</td>
</tr>
<tr>
<td>Salt</td>
<td>0.15</td>
</tr>
<tr>
<td>Vanillin</td>
<td>0.02</td>
</tr>
<tr>
<td>Water</td>
<td>2.33</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Recommended Fats

Palm oil can replace butter fat, weight for weight, although it does not give the same flavour. However, there are now synthetic materials with almost identical flavour to butter and possessing good carry through properties.

ICE CREAM

Ice cream is an oil-in-water emulsion containing milk solids, a very popular food in most countries. Its composition is, therefore, generally legislated. Scrupulous hygiene is a pre-requisite.

Typical legal requirements are (UK):

- Milk fat  5% min
- Or non-milk fat  7.5% min

The ice cream emulsion is extremely susceptible to bacterial attack, and most countries specify strict heat treatment.

Fats Used

Milk fat is, of course, the traditional fat, and in the USA, still the only fat allowed. Similar products made with vegetable fat are called ‘mellorine’. In most European countries, however, vegetable fats have replaced milk fat, and only ‘dairy’ ice cream has to be made with milk fat.
Good ice cream cannot be made with liquid oil since the emulsion will have poor whipping properties with insufficient air inclusion and lacking ‘body’. Vegetable fats must have a relatively high solid fat content at around 0ºC, with a melting point of 25 – 35ºC, although up to 40ºC is acceptable.

The lauric oils, e.g., from coconut and palm kernel oils, which have a sharp melting property, are usually considered superior for this application. But in the UK and elsewhere in Europe, palm oil is more commonly used, especially by the larger producers, as it generally offers the best compromise between quality and price. For even lower cost, mixtures, palm oil with 10 – 15% palm stearin can be used.

Recommended fats are:

- 100% coconut oil or palm kernel oil
- 100% palm oil
- 90%/10% palm oil/palm stearin

Ice Cream Powder

Ice cream powder is a new product. It can be conveniently reconstituted to meet a sudden demand for ice cream. Other advantages are the ease of packing, transport and hygiene.

The ingredients are palm oil, skim milk powder, corn syrup solids, sugar, protein and small amounts of emulsifier, stabilizer, flavours and (optional) colouring. The moisture content of the dry product should be no more than 1.5 - 2.0%.
FILLED MILK

Since fresh milk is perishable and since many food products require dried milk, milk powder is a big product. It is often expensive and has a very short shelf life. Also, many people, especially in African and Asian countries, have milk intolerance, while others avoid animal fats (to reduce cholesterol intake, etc.). As a result, in many applications, the fat in milk is replaced with vegetable fat, and the milk then spray-dried. The ‘replaced’ product is ‘filled milk powder’.

Milk powder has very large surface area and milk is also extremely susceptible to deterioration, resulting in off flavours easily detectable by the consumer. Thus, only bland fats with high stability can be used.

Fats for filled milk (evaporated, condensed or powder) are:

- 100% palm oil
- 100% palm olein
- 100% fully hydrogenated coconut oil (IV max 2)
- 100% fully hydrogenated palm kernel oil (IV max 2)
- 100% hydrogenated palm olein 30 - 38°C
- 100% hydrogenated palm oil 40/42°C (Hydrogenation should be under highly selective conditions).
- 50%/50% hydrogenated palm oil 40/42°C/hydrogenated palm kernel oil 38°C (A high quality blend using the strong eutectic effect of the two oils).

COFFEE WHITENER (CREAMER)

Coffee whiteners can be fluid or powdered. The most popular is dry powder similar to filled milk powder. They replace cream for coffee or tea and offer great advantages in shelf life and convenience.

Coffee whiteners contain higher fat than filled milk (for richness and whitening power) and special additives to render them free-flowing and easily wettable. As with filled milk, the fat must have high resistance to oxidation and flavour reversion. Lauric oils are usually considered the best, but often too expensive. Nevertheless, they are used by most brand leaders in Europe, since coffee whiteners are premium products. Hydrogenated palm oil is a good second choice, and very popular for the lesser brands and for those used in catering.

Fats for coffee whiteners:

- 100% fully hydrogenated coconut oil or palm kernel oil
- 100% hydrogenated palm olein 40°C
- 100% hydrogenated palm oil 42°C
PALM SANTAN POWDER

Santan, or coconut milk, is the liquid from pressing (old) coconut flesh, used widely in Asian foods. Palm oil ‘santan’ has been formulated by MPOB. Its nutrient composition is similar to those of commercial products with 60.5% fat, 29.7% carbohydrate, 7.35% protein, 1.82% moisture and 0.65% ash. The slip melting point of the palm oil used is 34.5 – 36.0°C. Other ingredients can be added - flavours and anti-caking agents. The advantages of palm oil santan (as powder) are easy handling, longer shelf life, resistance to deterioration and good nutritive value.

Cendol, a Malaysian dessert made with palm santan powder

PALM PROCESSED CHEESE

Processed cheese is made by blending natural cheese (young, mature, etc.) with water, colouring matter, emulsifying salts, followed by heating and agitation to a homogenous mixture. The basic ingredients are cheese, cheese base, water, emulsifying salt and palm oil blend. Mature cheddar is included to enhance flavour and aroma. The final moisture content for block processed cheese is about 45%. Different fractions of palm-based oils, e.g., 30% palm oil and 70% palm kernel olein, are blended and used.

The advantage of using palm products is to improve the nutritional value, functionally and shelf life of the cheese.

Processed cheese using palm oil is of comparable quality to normal cheese
MICROENCAPSULATED PALM OIL PRODUCTS

Microencapsulation is a technique of coating droplets of liquid oil or solid fat particles (core material) with a thin film to protect the core material from deterioration.

Microencapsulated palm products, such as carbohydrates, gums and proteins, have several advantages:

- The core material is protected against light, oxygen and moisture.
- The nutritive value of the core material is not lost in extended storage under normal conditions.
- Free flowing powder is easier to pack and handle.
- The microencapsulated core material can easily be incorporated in many food systems.

The potential applications of microencapsulated palm products are wide and diverse. Examples are instant soap mixes, cake mixes, dessert mixes, coffee creamer, sauces and ice cream.
Yoghurt originated from the Balkans. It is a unique product in that it supplies the vital nutrients of milk as well as the metabolic products of fermentation along with abundant live and active yoghurt culture.

Yoghurt production involves heating homogenized milk to 85 – 95°C and then cooling before inoculation with a starter culture. The mixture is then incubated at 42°C for a few hours until the titratable acidity is 0.85 – 0.95% and pH 4.0 – 4.5. In producing palm yoghurt, the palm blend is incorporated at different levels (2–5%). Processing is similar to that for natural yoghurt, the only difference being butterfat substituted by a palm oil blend with similar SFC profile as milk fat. Sensory evaluation showed that 5% palm yoghurt obtained the highest score. The product can be improved by adding flavours, such as pineapple, lychee and strawberry.
The common oils used in salad dressings include sunflower, corn, soybean and canola. Palm and peanut oils are not used because they tend to break the emulsion at low (refrigerated) temperature. MPOB has investigated palm olein for salad dressing, and found olein of IV 60 – 67 suitable as salad oil and for making salad dressing.

The basic ingredients to make a palm salad dressing are palm olein with IV 60 - 67, egg yolk, vinegar, starch, sugar, salt, mustard and water.

The advantages of palm olein are its consistent supply and competitive price compared to other vegetable oils. Furthermore, the olein has superior oxidative stability due to its lower IV and high content of vitamin E, a natural antioxidant.

Palm Oil Fact

Palm fruit oil is odorless and tasteless, perfect for consumers and manufacturers alike looking for a healthy oil for cooking and baking needs.
SOUP MIXES (DRY)

Market leaders in this industry have, in recent years, been replacing meat fats with hydrogenated vegetable fats. The main requirements are good stability, high solids at room temperature and competitive price. Hydrogenated palm oil is now the standard in these products.

For dry soups, the fat is often spray-dried to a free flowing powder after encapsulation in sodium caseinate. For this application, hydrogenation of the palm oil should be under highly selective conditions. Such fats have higher SFC at ambient for a given melting point.

Vegetable fats are also used in canned soup in lieu of animal fats. In this product, the minimum fat content is, in most countries, regulated according to whether the soup is ‘cream’ soup. The recommended fats are:

**Dry soup mixes**

<table>
<thead>
<tr>
<th>Fat Type</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogenated palm oil 42/44°C</td>
<td>100%</td>
</tr>
</tbody>
</table>

Fats of relatively high melting point are used because soups are invariably consumed hot, except some very uncommon types.

**Canned soup**

<table>
<thead>
<tr>
<th>Fat Type</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>PO or POo</td>
<td>100%</td>
</tr>
</tbody>
</table>

EMULSIFIERS

(MONO- AND DIGLYCERIDES)

Mono- and diglycerides, also called mono- and diacylglycerols, are oil-soluble surfactants used as emulsifiers on quite large scale for enhancing shortening and margarine in baking and other edible applications. They can also be intermediates in the production of detergents, alkyd resins and other non-edible applications.

The manufacture of these partial glycerides involves reacting oils and fats with glycerol at high temperature (around 250°C) in the presence of a suitable catalyst, such as sodium ethoxide or sodium hydroxide. This reaction is called glycerolysis, a special case of alcoholysis. The reaction product is a mixture of monoglycerides, diglycerides and triglycerides. The usual level of monoglycerides is 40 – 45% but can be concentrated to >90% by molecular distillation.
At the end of the reaction, the catalyst is inactivated with dilute phosphoric acid. If this is not done, another very useful emulsifier, called self-emulsifying monoglycerides, which contains about 32% monoglycerides and 2% soap, is obtained. This special product has a unique property of forming emulsions more rapidly with water in food products without imparting any soapy taste. For ‘high-ratio’ shortenings, partial glycerides from vegetable oils have better market image. Palm oil, of course, fits this requirement very well, and has the additional advantage of imparting good resistance to autoxidation in the product as partial glycerides tend to be more susceptible to oxidation than the fats from which they are made (due to loss of tocopherols) and, thus, feedstocks of high stability are preferred.

**ANIMAL FAT REPLACERS**

Animal fats have been singled out as the cause of dietary diseases due to their saturated fatty acid and trans fatty acid contents. However, animal fat is still one of the major ingredients in processed meat formulations, such as burger, frankfurter and nugget. Animal fat substitution has been done in many meat and vegetarian foods – either direct using palm fat or indirect with a modified emulsion.

In the modified emulsion, both palm oil and palm olein can be used interchangeably. The hydrocolloids in the emulsion enable homogenous distribution and incorporation of the palm fat in the product and also reduce oil absorption during frying.

Vegetarian nugget has been formulated with more protein and fibre than commercial chicken nugget (Figure 14). The basic formulation of vegetable nugget is shown in Table 31.

Palm vegetable nuggets.
Figure 14. Nutritive composition of pre-fried nuggets.

TABLE 31. BASIC FORMULATION FOR VEGETABLE NUGGET

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emulsion (Blend of palm olein IV 60/ oil, stabilizers and water)</strong></td>
<td>8–10</td>
</tr>
<tr>
<td>Potato</td>
<td>24–27</td>
</tr>
<tr>
<td>Flour</td>
<td>20–23</td>
</tr>
<tr>
<td>Oats</td>
<td>8–10</td>
</tr>
<tr>
<td>Vegetables</td>
<td>17–20</td>
</tr>
<tr>
<td>Salt</td>
<td>0.5–0.9</td>
</tr>
<tr>
<td>White pepper</td>
<td>0.7–1.0</td>
</tr>
<tr>
<td>Protein (tofu/gluten/tempeh)</td>
<td>20–23</td>
</tr>
</tbody>
</table>
CHAPTER 4:
OLEOCHMICALS AND NON-FOOD USES
INTRODUCTION

Malaysia is currently the world’s largest exporter of palm oil, palm kernel oil and their products. In 2015, it produced 19.96 million tonnes palm oil and 2.28 million tonnes palm kernel oil.

The plentiful and consistent supply of the oils has spawned the Malaysian oleochemicals industry, now one of the largest in the world with about 20% of the global capacity. In 2015, about 3.0 million tonnes of the oils were processed into oleochemicals, mainly for export (Figure 15) to more than 100 countries. The major products were fatty acids, fatty methyl esters, fatty alcohols and glycerol (Figure 16) to the major markets in Figure 17.

The export of oleochemicals is expected to increase dramatically due to the increasing demand and competitiveness of palm products. For example, soap noodles has achieved tremendous market growth with export of 464,600 tonnes in 2015, an increase of 6.7% over 2014 (Figure 18). In addition, the industry is continuously venturing further downstream into higher value products.

Figure 15. Malaysian oleochemicals: Capacity, production and exports (’000 tonnes).
Figure 16. Oleochemicals exported by Malaysia (tonnes).

Figure 17. Major regions Importing Malaysian oleochemicals (’000 tonnes).
OLEOCHMIC APPLICATIONS

General

Most palm oil is used for food with less than 20% in non-food applications. Nevertheless, non-food is an important use as the oil is processed into higher value products.

Oleochemicals are chemicals derived from oils and fats. However, there are ‘natural oleochemicals’ (from vegetable and animal oils and fats) and ‘synthetic oleochemicals’ (from petroleum). Vegetable oils/fats are triglycerides formed from one molecule of glycerol and three molecules of fatty acids. The break-up of oils/fats, i.e., hydrolysis into fatty acids and glycerol, is the basis of the oleochemicals industry.

Using water or alcohol, oils/fats can be hydrolysed to fatty acids or esters (organic salts), respectively, and glycerol. The fatty acids or esters are the basic building blocks in oleochemistry - used to produce fatty alcohols and fatty nitrogens, and, in turn, further derivatives. Thus, oleochemicals are often divided into basic oleochemicals and derivatives. The most common basic oleochemicals are fatty acids, fatty methyl esters, fatty alcohols, fatty amines and glycerol.

The derivatives are produced by further reacting the basic oleochemicals such as by epoxidation, ethoxylation, sulphation and sulphonation. Infinite possibilities exist for different chemicals. A schematic representation of the reactions is given in Figure 19.

Palm oleochemicals have better odour and colour than those from low grade tallow, and also their higher C16 content and vegetable origin are advantages in many applications.
FATTY ACIDS

Commercial fatty acids are derived almost entirely from natural fats. As the basic building blocks for oleochemicals, they are in high general demand.

The main fats for fatty acid production are inedible tallow for C16 - C18 acids and coconut oil (CNO) for C12. Historically, the former was a cheap and abundant source of C16 - C18, while the latter was virtually the only source of lauric (C12).

But palm oil and palm kernel oil are equally rich sources of these acids, and in recent years, have greatly overtaken tallow and CNO in their use. They are competitive in price and increasingly used in fatty acid production.

The fatty acid composition of the major oils and fats used in the oleochemicals industry are given in Table 32.
TABLE 32. PROXIMATE FATTY ACID COMPOSITION OF MAJOR OILS AND FATS USED IN OLEOCHEMICAL PRODUCTION

<table>
<thead>
<tr>
<th>Fatty acid (%)</th>
<th>Tallow</th>
<th>Palm Oil</th>
<th>Palm Stearin</th>
<th>Coconut Oil</th>
<th>Palm Kernel Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:0 and lower</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>12:0</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>47</td>
<td>48</td>
</tr>
<tr>
<td>14:0</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>16:0</td>
<td>27</td>
<td>44</td>
<td>60</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>16:1</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>18:0</td>
<td>20</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>18:1</td>
<td>39</td>
<td>40</td>
<td>26</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>18:2</td>
<td>3</td>
<td>10</td>
<td>7</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Fatty acids can be used directly in rubber processing, and to make candles and cosmetic products or as feedstock to produce derivatives, such as medium chain triglycerides (MCT), soap and metallic soap and intermediate chemicals like fatty alcohols.

**METHYL ESTERS**

The methyl esters of fatty acids are an alternative to oleochemical derivatives. After fatty acids, they are the biggest volume oleochemicals. Nevertheless, methyl esters are reactive compounds possessing several advantages over fatty acids, e.g., in energy requirements, storage stability and being non-corrosive.

Direct applications of fatty methyl esters are limited, although used to produce very white soap, especially in Japan, and as a diesel substitute. They are mostly used as intermediates to produce fatty alcohols, methyl ester sulphonates (MES), sucrose esters and other fatty esters, alkanolamides, antibiotics and defoamers.

The esters are produced by transesterification or alcoholysis - reacting fats with methyl alcohol in the presence of an alkaline catalyst. Glycerol is a valuable by-product. Alternatively, esterification can be used - reacting fatty acids with alcohol - but no glycerin is produced.
The reactions are:

1. Alcoholysis or transesterification of fats (at 60°C)

\[
(RCOO)_3C_3H_5 + 3\text{MeOH} \rightarrow 3\text{RCOOME} + C_3H_5(\text{OH})_3
\]

Fat + Methanol → Methyl Ester + Glycerol

2. Esterification of fatty acids

\[
\text{RCOOH} + \text{MeOH} \rightarrow \text{RCOOME} + \text{H}_2\text{O}
\]

Fatty acid + Methanol → Methyl Ester + Water

As oils and fats are cheaper than fatty acids, and they also yield glycerol, alcoholysis (reaction 1) is the method preferred.

**FATTY ALCOHOLS**

Fatty alcohols are the most important group of downstream products from fatty acids. One of their major uses is to manufacture sodium alkyl sulphate, a surfactant for detergents.

**Production**

Two methods are used to produce fatty alcohols - high pressure hydrogenation of fatty acids and reduction of fatty esters.

a) High pressure hydrogenation of fatty acids:

\[
\text{RCOOH} + 2\text{H}_2 \rightarrow \text{RCH}_2\text{OH} + \text{H}_2\text{O}
\]

Fatty Acid + Hydrogen → Fatty Alcohol + Water

The reaction is carried out at about 200 bar pressure with copper chromate as catalyst in stainless steel equipment. This has a lower manufacturing cost than (b).

b) Reduction of a fatty ester with metallic sodium in methanol:

\[
\text{RCOOME} + 4\text{Na} + 3\text{MeOH} \rightarrow \text{RCH}_2\text{OH} + 4\text{NaOMe}
\]

Methyl Ester + Sodium + Methanol → Fatty Alcohol + Sodium Methoxide

This method has the advantage that it does not hydrogenate the alkyl group and the fatty alcohol retains its original unsaturation. Another advantage is its lower capital investment.

The choice between the two depends on individual preferences.
FATTY ACID AMIDES

Fatty acid amides, RCONH₂, are fatty acids with their hydroxyl group (OH) replaced by an amino group (-NH₂). Amides have a high melting point, good stability and water repellency, and diverse applications, such as in the production of textiles, paper, wood, metal and rubber. They can also replace expensive hard waxes (carnauba, montan) in polish, be anti-adhesion agents and confer slip and gloss to ink.

Manufacture

Fatty amides can be prepared several ways, but the most widely used is direct reaction of fatty acids with anhydrous ammonia, i.e.,

$$\text{RCOOH} + \text{NH}_3 \rightarrow \text{RCONH}_2 + \text{H}_2\text{O}$$

normally at 150 - 200°C and 10 bar (150 psig) pressure in stainless steel reactors.

Some well-known amides are stearamide (melting point, MP, 108.5°C) and oleamide (MP 75.9°C). Palm oil with an approximate composition of 45% palmitic, 5% stearic, 40% oleic and 10% linoleic acids, or, after hydrogenation, 45% palmitic and 55% stearic, is a good source of the fatty acids for amide production.

FATTY AMINES

Fatty amines can be regarded as compounds of fatty acids and ammonia, with one or more of the hydrogen atoms in ammonia replaced by the alkyl radical (RCH₂). Amines have wide applications on their own merit and are also the starting blocks for a number of derivatives.

Their importance is based on their cationic properties of having a basic pH (>7) and being biologically active with strong adsorption on many surfaces, thus altering the properties of the materials mixed with them.
The basic reactions for their manufacture are:

Reaction of fatty acid with ammonia to give nitrile.

\[
\text{RCOOH} + \text{NH}_3 \rightarrow \text{RCN} + 2\text{H}_2\text{O}
\]

\[\text{Fatty Acid} \quad \text{Ammonia} \quad \rightarrow \quad \text{Nitrile} \quad \text{Water}\]

followed by hydrogenation of the nitrile

\[
\text{RCN} + 2\text{H}_2 \rightarrow \text{RCH}_2\text{NH}_2
\]

\[\text{Nitrile} \quad \text{Hydrogen} \quad \rightarrow \quad \text{Primary Amine}\]

This last reaction is usually at about 150°C and 13 bar pressure using Raney nickel catalyst in stainless steel reactors.

There are primary, secondary and tertiary amines according to the number of alkyl groups in the molecule. The industrial products are often named after the raw materials from which they derive, e.g., tallow amine, palm amine, etc.

Their major uses are in ore flotation, corrosion inhibition, manufacture of textiles (anti-static and waterproofing), petroleum recovery, lubricants, etc.

**QUATERNARIES**

This is another class of nitrogen derivatives, commonly known as quats, made by further reacting fatty amines. They are cationic surface-active agents with powerful bactericidal and disinfectant properties. Their main uses are in fabric softeners, conditioners, antimicrobial disinfectants, textiles and paper softeners.

**GLYCEROL**

Glycerol is a polyhydric alcohol, a clear, odourless viscous liquid with a sweet taste and hygroscopic nature. It is a valuable by-product from the oleochemicals industry, primarily from the production of fatty acids, fatty esters or soap from oils and fats.

Glycerol has wide applications, such as:

- Solvent or drug carrier in pharmaceutical products
- Humectant in cosmetics and tobacco
- Anti-freeze or heat-transfer agent
- Hydrofluid, and
- Plasticizer/stabilizer for less polar polymers.

It is also used to produce other chemicals, e.g., nitroglycerin (explosive), polyesters for use in grease/lubricants, polyol for the production of polyurethane, and mono- and diglycerides (food emulsifiers).
EPOXIDIZED PALM OIL

Epoxidized vegetable oils are those which carbon atoms adjacent to the alkyl group are joined to the same oxygen atom in the structure:

They have wide uses as plasticizers/stabilizers in the plastics industry, finishing of polyacrylate surfaces and as starting materials for the production of polyols (key components in the production of polyurethane).

There are two methods of production, using:

a) Industrial peracids (such as peracetic acid and performic acid), or

(b) Peracids generated in situ

\[
\begin{align*}
    & \text{Palm oil} & \text{Hydrogen Peroxide} & \text{Formic Acid} & \text{Epoxidized Palm Oil} & \text{Water} & \text{Formic Acid} \\
    & \text{O} & \text{O} & \text{O} & \text{O} & \text{O} & \text{O}
\end{align*}
\]

The major oil used is soybean oil, but palm oil also gives good results.

SOAP

Soap is the sodium or potassium salt of fatty acids. In South East Asia, soap is primarily made from palm oil blended with either coconut oil (CNO) or palm kernel oil (PKO).

There are two major processes for soap manufacture:

1. Saponification of fats

\[
\begin{align*}
    (\text{RCOO})_2\text{C}_3\text{H}_5 + 3\text{NaOH} & \rightarrow 3 \text{RCOONa} + \text{C}_3\text{H}_5(\text{OH})_3 \\
    \text{Fat} & \text{Sodium Hydroxide} & \text{Soap} & \text{Glycerol}
\end{align*}
\]

2. Neutralization of fatty acids
A third process for which certain advantages are claimed was developed by Lion, a Japanese company - reacting fatty acid methyl esters with sodium hydroxide:

3. \[ \text{RCOOCH}_3 + \text{NaOH} \rightarrow \text{RCOONa} + \text{CH}_3\text{OH} \]

Methyl Ester Sodium Soap Methanol

Hydroxide

The claimed advantages are that methyl esters are less corrosive, less prone to discoloration and have a lower melting point than fatty acids, all lending to certain economies in manufacture. Methyl esters can be better purified than fatty acids, and give better quality soap. But the claims are not yet verified, and the choice of production method will depend on the careful assessment of many factors, such as scale of production, capital expenditure and availability of raw materials.

The typical fatty acid composition of common oils and fats used for making soap are shown in Table 33.

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>Tallow</th>
<th>Palm Oil</th>
<th>Palm Stearin</th>
<th>Coconut Oil</th>
<th>Palm Kernel Oil</th>
<th>Palm Kernel Olein</th>
</tr>
</thead>
<tbody>
<tr>
<td>C8:0</td>
<td></td>
<td>7.6</td>
<td>1.4</td>
<td>4.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C10:0</td>
<td></td>
<td>7.3</td>
<td>2.9</td>
<td>3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C12:0</td>
<td>0.3</td>
<td>0.7</td>
<td>48.2</td>
<td>50.9</td>
<td>42.6</td>
<td></td>
</tr>
<tr>
<td>C14:0</td>
<td>3.4</td>
<td>1.1</td>
<td>1.5</td>
<td>16.6</td>
<td>18.4</td>
<td>12.4</td>
</tr>
<tr>
<td>C16:0</td>
<td>26.3</td>
<td>43.1</td>
<td>55.7</td>
<td>9.0</td>
<td>9.7</td>
<td>8.4</td>
</tr>
<tr>
<td>C18:0</td>
<td>22.4</td>
<td>4.6</td>
<td>4.8</td>
<td>3.8</td>
<td>5.0</td>
<td>2.5</td>
</tr>
<tr>
<td>C18:1</td>
<td>43.1</td>
<td>39.3</td>
<td>29.5</td>
<td>5.0</td>
<td>14.6</td>
<td>22.3</td>
</tr>
<tr>
<td>C18:2</td>
<td>1.4</td>
<td>10.7</td>
<td>7.2</td>
<td>2.5</td>
<td>1.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Others</td>
<td>3.4</td>
<td>0.9</td>
<td>0.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Other parameters**

<table>
<thead>
<tr>
<th>IV (WIJS)</th>
<th>Sap value</th>
<th>Titré, °C</th>
<th>Glycerol yield (wt %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>195</td>
<td>41</td>
<td>10.7</td>
</tr>
<tr>
<td>53</td>
<td>198</td>
<td>45</td>
<td>10.8</td>
</tr>
<tr>
<td>35</td>
<td>200</td>
<td>51</td>
<td>11.0</td>
</tr>
<tr>
<td>8</td>
<td>250</td>
<td>22</td>
<td>14.1</td>
</tr>
<tr>
<td>8</td>
<td>245</td>
<td>22</td>
<td>13.4</td>
</tr>
<tr>
<td>23</td>
<td>239</td>
<td>20</td>
<td>13.0</td>
</tr>
</tbody>
</table>
Formulation

The soap making properties of fats depend almost entirely on their fatty acid composition (FAC). The FAC affects the following three important test parameters:

1. Saponification value (SV), which determines the amount of alkali needed to produce the soap, and the glycerol yield.
2. Iodine value (IV), which indicates the unsaturation of the oil and, therefore, the oxidative stability of the soap.
3. Titre, which determines the hardness of the soap from fats of similar saponification values. Mixtures of oils have only their approximate average titre because of eutectic formation and other reasons.

Tallow and coconut oil (CNO) are the traditional fats used for soap. Tallow (cheaper) gives a hard slow-lathering soap, while CNO (more expensive) a hard quick lathering soap. For all-round quality, CNO is usually 20%-25% but cheap soaps have as low as 2% CNO, or even none at all.

Palm oil has very similar soap-making properties to tallow, except that its titre is slightly higher. It can replace part or all the tallow with only minor adjustments. Palm stearin, however, is much harder and needs the addition of soft oils.

PKO is so similar to CNO that it can replace it wholly without any adjustment to the processing conditions. Because of its rapidly increasing supply and big discount to CNO, the potential of PKO in soap making is promising. Palm kernel olein (PKOo), from the fractionation of palm kernel oil, is another suitable raw material for soap making.

Typical Palm Blends:

Some palm soap blends commonly used in Malaysia are.

80% PO : 20% PKO
75% PO : 25% PKO
70% PO : 30% PKO
60% PO : 40% PKO
40% PO : 40% POs : 20% PKO
70% POs : 30% PKOo

In countries where tallow is easily available, the typical tallow blend is 75% T: 25% CNO/ PKO. Palm oil, palm stearin and their distilled fatty acids can replace part or all the tallow, according to the type and quality of soap required.

Palm Stearin In Soap Making

Replacing tallow with palm stearin is based on the fact that stearin yields 11% glycerin vs. 10% from tallow. It also has a higher saponification value and thus requires less admixture of palm kernel or coconut oil, making it more cost-effective. Typical blends of palm materials and tallow are 40% T:40% PO: 20% PKO and 40% T: 40% POs: 20% PKO.
Advantages of Palm Oil Products

- Fatty acids are mostly C16 and C18;
- Wider range of titre, e.g. tallow, 38 - 42°C and palm oil products, 35 - 55°C;
- Readily available RBD grades which need no further processing (bleaching or refining) for soap making;
- Higher resistance to oxidation and better perfume retention;
- More acceptable odour even when the oils are not fully refined (deodorized). Tallow has a strong and unpleasant stench; and
- In Muslim and Jewish societies, vegetable oils are more acceptable than animal products.

Specifications

Neutralization of fatty acids or saponification of fats/oils with alkali for soap making always requires excess alkali for complete neutralization or saponification. Thus, soap bases usually contain 0.04 – 0.08% free caustic soda (NaOH).

The latest development is acidic soap because alkaline soap can irritate skin, which is normally acidic. It is usually produced by adding fatty acids (similar to those in the blend or other fatty acids) to the soap base, to an excess of 0.6 – 3.0%, depending on the requirement.

Certain Difficulties with Palm oil Products

Palm stearin has a much higher titre than tallow, and when high proportions are used, should be counter-balanced by adding an oil(s) of lower titre in the formulation. Additives can also be used to soften the soap to prevent cracking. Colour reversion only occurs with low quality palm raw materials.

Super-Fatting

Super-fatting is another means of preventing cracking in soap. Soap with high titre tends to crack, hence super-fatting agents are added, e.g. stearic acid, palm oil fatty acids coconut fatty acids. The agents impart a moisturizing effect, good skin-feel, mild and better lather volume and good plasticity to the soap.

Transparent/Translucent Soap

The commonly used fats/oils for these soaps are tallow, RBD palm oil, RBD PKO, CNO, castor oil and rosin. Additives, such as polyglycols, can enhance the transparency. In Malaysia, transparent/translucent soaps are made from palm oil, PKO and their products.
The total fatty matter of commercial transparent and translucent soaps is 7.1 - 77.4%. The moisture content also varies, depending on whether transparent or translucent. Free caustic is <0.5%, and the transparency value for transparent soap is >0.60 and for translucent soap 0.40–0.60 (values from MPOB transparency meter). Recently, palm dihydroxyystearic acid (DHSA), added at 1 - 5%, was found to enhance the transparency.

Laundry Bars

Laundry soaps are used for general house cleaning. There are two types - white and yellow. White is usually made from 25 - 40% coconut oil or PKO and 60 - 75% tallow, palm oil, palm stearin or PFAD. To the soap base is usually added sodium silicate or other builders, reducing the anhydrous soap content to 50%. The anhydrous soap content of yellow soap is >50% and its C12 - C14 fatty acid content is lower than in the white variety. Palm laundry soap usually contains ≥75% total fatty matter, and has a titre of about 42°C, hardness of 16 mm, chloride content of 1.0%, pH of 9.7 and alcohol insolubles of 0.35%. Most laundry bars are made from PFAD a by-product from the physical refining of palm oil, or palm acid oil, a by-product from chemical refining.

METAL SOAPS

Besides sodium or potassium soap, soap made from other metals are also available, normally called ‘metal soap’.

Metal soaps have wide and increasing uses, particularly in the manufacture of lubricants, greases, paints, varnishes and plastics. More recently, they have also found extensive use as high-energy supplements in animal feed.
Manufacture

Metal soaps are made by one of three basic processes:

1. **Dry or fusion process - fatty acid or fat reacted with a metal hydroxide at elevated temperatures:**

   \[
   2\text{RCOOH} + \text{Pb(OH)}_2 \rightarrow (\text{RCOO})_2\text{Pb} + 2\text{H}_2\text{O}
   \]

   Fatty Acid      Lead Hydroxide                 Lead Soap              Water

   If a fat is used instead of fatty acids, the glycerin released can either be left in the soap or washed out and this will have a bearing on the properties of the final product.

2. **Wet neutralization process - fatty acids reacted with metal hydroxide at around 100°C, e.g.;**

   \[
   2\text{RCOOH} + \text{Ca(OH)}_2 \rightarrow (\text{RCOO})_2\text{Ca} + \text{H}_2\text{O}
   \]

   Fatty Acid      Calcium Hydroxide calcium soap       Water

   The reaction is highly exothermic.

3. **Wet, or double decomposition process - sodium soap reacted with a metal salt, e.g.**

   \[
   2\text{RCOONa} + (\text{CH}_3\text{COO})_2\text{Pb} \rightarrow (\text{RCOO})_2\text{Pb} + 2\text{CH}_3\text{COO Na}
   \]

   Sodium Soap     Lead Acetate                          Lead Soap             Sodium Acetate

   The three processes yield products of different appearance, density and colour, and the choice depends on their applications.

Palm stearin, PFAD and distilled palm oil fatty acids are richer in palmitic acid than any other raw material and are vegetable. They give metallic soaps with distinctive properties, better odour and oxidative stability.

Soaps made from PKO and hydrogenated PKO are virtually indistinguishable from those made from CNO and hydrogenated CNO.

**SURFACTANTS AND CLEANING PRODUCTS**

A surfactant, or surface-active agent, is a molecule with amphipathic moieties, and which preferentially sits at the interface when placed in two immiscible media. With a two-part structure comprising a hydrophobic tail attached to a hydrophilic head, surfactants exhibit very useful properties as wetting agents, emulsifiers, dispersants, solubilisers, etc. Their most important application is in detergent and cleaning products. The majority of surfactants are produced either from petrochemical or oleochemical feedstocks. Some examples are given in Table 34.
### TABLE 34. TYPES OF SURFACTANTS

<table>
<thead>
<tr>
<th>Surfactant</th>
<th>Petrochemical</th>
<th>Oleochemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anionic</td>
<td>1. Linear alkyl benzene sulphonates (LAS or LABS)</td>
<td>1. Alpha-sulphonated methyl ester (α-SME, MES or ASME)</td>
</tr>
<tr>
<td></td>
<td>2. Alcohol sulphates (AS)</td>
<td>2. Alcohol sulphates (FAS or SLS)</td>
</tr>
<tr>
<td></td>
<td>3. Alcohol ether sulphates (AES)</td>
<td>3. Alcohol ether sulphates (FAES or SLES)</td>
</tr>
<tr>
<td></td>
<td>4. Alpha-olefin sulphonates (AOS)</td>
<td>4. Soap</td>
</tr>
<tr>
<td>Cationic</td>
<td></td>
<td>1. Quaternary ammonium compounds (quats)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Esterquats</td>
</tr>
<tr>
<td>Nonionic</td>
<td>1. Nonyl phenol ethoxylates (NPE)</td>
<td>1. Alcohol ethoxylates (FAE)</td>
</tr>
<tr>
<td></td>
<td>2. Alcohol ethoxylates (AE)</td>
<td>2. Alkyl polyglucosides (APG)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Alkanolamides</td>
</tr>
<tr>
<td>Amphoteretic</td>
<td></td>
<td>1. Amine oxides</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Betaines</td>
</tr>
</tbody>
</table>

Alpha-sulphonated methyl esters (α-SME), commonly known as methyl ester sulphonates (MES), is a surfactant obtained by direct sulphonation of palm oil methyl esters.

Research has confirmed the superior properties of palm MES in detergency, biodegradability and tolerance to different water hardness in comparison to linear alkyl benzene sulphonates (LABS). Furthermore, the cost of production of MES is lower than for LABS.

Palm MES can be formulated into detergents and cleaning products with detergency, foaming power and wetting characteristics comparable, if not better, to some cleaning products in the market. The products are also readily biodegradable in the aquatic environment.
Cosmetics and personal care products can be divided into four main categories - skin care, colour cosmetics, hair care and oral care. Skin care includes moisturizing and anti-wrinkle cream, shower bath and body deodorant. They are prepared as lotion, cream, liquid, gel and stick, and can be made from palm oleochemicals, such as glycerin, fatty acids and fatty alcohols. The amount of palm materials in the formulations is 45 - 98%. The formulations can be enhanced by incorporating active ingredients, such as palm vitamin and goat’s milk, to capture niche markets.

Colour cosmetics include lipstick or lip gloss, foundation and eye shadow. Lipstick is a mixture of emollients and waxes, strong enough to form a moulded stick with various additives, primarily pigments and specialty ingredients, such as vitamins and preservatives. Normally, the emollients are medium chain triglycerides (MCT), isopropyl myristate (IPM) and isopropyl palmitate (IPP) which provide lubricity to the lips. A good lipstick can be produced using up to 51 - 57% palm materials. These lipsticks are easily applied, and possess good covering power and spread. Besides the colour and feel, users also look at the efficacy of the product. 2-in-1 lipsticks, for example, are gaining popularity with active ingredients, such as vitamins E and C, flavour extracts and goat’s milk added to the lipstick base.

Foundation, or liquid make-up, is an emulsion with dispersed pigment. A mixture of inorganic pigments, such as red iron oxide, yellow iron oxide and titanium oxide, is used in combination for matching various shades of skin colour. The emulsion, or base foundation, can be formulated with up to 85% palm materials. To cover natural fine wrinkles on the face, and for protection against the harmful effects of sunlight, other functional ingredients, such as anti-wrinkle agents, moisturizer and sunscreen, can be added. The products should spread smoothly, easily and cover well without a tacking after-feel on the skin face.
Compact powder, or compact paste, and eye shadow contain talc, kaolin, magnesium stearate, zinc stearate, and a fatty acid ester or oil-based binder. The binders are normally isopropyl stearate, cetyl palmitate and/or medium chain triglycerides. Only 5% binder is used. Dihydroxystearic acid (DHSA) is a potential new ingredient developed by MPOB for cosmetics. Coating the pigment with DHSA will increase the hydrophobicity of the final product, thus providing a velvety skin feel, increasing skin adhesion and improving its long-term performance. Zn-DHSA coated pigment, for example, eases the distribution of the product on the skin and improves skin lightness.

Hair care products include shampoo and conditioner. Shampoo removes excess sebum or oily materials from hair. The cleansing ingredients are usually mixtures of anionic and amphoteric surfactants, normally 12 - 20% of the formulation. Palm materials commonly used are sodium lauryl sulphate, sodium myristyl sulphate and sodium laureth sulphate. Other than surfactants, preservative, perfume, thickener and solubilizer are also included. To enhance niche or functional performance, other additives, such as vitamin B5, zinc pyrithione (an anti-dandruff agent) and UV protector, can be incorporated. Colour care shampoo and conditioner protect hair from the harmful effects of UV radiation, while colour care treatment shampoo can delay the fading of dyed hair. Both products can be formulated using palm materials.
Evaluation of Cosmetics and Personal Care Products

Efficacy tests are carried out for claim substantiation on cosmetics and personal care (CPC) products. The tests available in AOTD, MPOB, include *in vivo* safety, efficacy evaluation and microbiological examination. They are conducted to international standards. Two *in vitro* tests are also available - SPF test and Ocular and Dermal Irritection Assay System (IAS) for eye and skin irritation, respectively.

HOUSEHOLD CLEANING PRODUCTS

1. **Hand Wash**

Traditionally, soap, the oldest cleaning agent, is used for washing hands. Now, liquid hand wash has become popular. Combinations of surfactants, such as anionic-nonionic surfactants together, can enhance the cleaning properties. Both types of surfactants can be obtained from palm materials. MPOB has a palm anionic surfactant, SME or MES. Using MES, ‘Palm Touch Hand Wash’ was developed with better detergency than commercial products, even with ingredients of lower activity. Having a non-irritant surfactant, Palm Wash is gentle to the skin. Glycerin may be used as humectant as it keeps hands from drying after the washing.
2. **Methyl Esters as Cleaning Agent**

Industrial solvents, such as kerosene, turpentine, white spirit, etc., are used for stubborn stains. They can be used neat, although mostly formulated into products, such as engine degreaser, tar/paint/adhesive remover and hand cleaner. These solvents are usually quite harsh to human skin, and prolonged contact may cause skin problems.

Fatty acid methyl esters from vegetable oils, such as palm oil, can be used *in lieu* to a certain extent. They are less harmful to human health. Among the cleaning products developed using palm oil methyl esters are car care products, such as car wax, tyre cleaner and engine degreaser. These products have comparable performance to the commercial products with petroleum solvents. Other advantages include low volatility and good detergency because esters can improve the solvency of polar deposits in the engine and disperse them.

Another trend in hand wash is the increasing preference for the waterless type. Without water, this product can remove grease and dirt from hands, making it convenient for people on the move to who water is not readily available. Usually, it is a lotion or gel, sometimes with anti-bacterial agents to make it a hand sanitizer as well. Palm methyl ester can substitute for mineral oil or kerosene as solvent in waterless hand cleaner. The ester can be formulated into a heavy duty cleaner for mechanics and those likely to get heavily smeared in grease.

**PRINTING INKS**

There are four key ingredients in an ink:

- Pigments
- Solvents
- Vehicles
- Additives

The ingredients used will depend very much on what is desired from the ink. In general, there are several requirements:

- Correct rheology;
- Good drying and setting rate;
- Balance between properties of ink and water;
- Good compatibility of pigment(s) and additive(s);
- Stable and acceptable use properties;
- Easy handling;
- Cost competitiveness, and
- Readily available raw materials.
The current printing inks are mainly petroleum-based, but manufacturers are looking at renewable resources, with vegetable oils in the fore. Another reason to substitute is to reduce the emission of volatile organic compounds (VOC) with the vogue in health consciousness. There is also worry about the after-life of prints with their eventual disposal to the environment. Will the petroleum inks, not so biodegradable, leach out and contaminate the environment?

Over the years, vegetable oils have crept in. In the US today, more than one-third of newspapers use soybean oil ink. This has been encouraged by the air quality regulations as petroleum ink has higher emission of VOC.

A palm oil offset printing ink has been developed by MPOB. Typically, palm components constitute 10 - 40% in web offset ink, depending on the colour required. And, indeed, palm inks have better tack and print stability than the conventional petroleum ones. Some other advantages of palm web offset ink are:

• No additional/modification of existing facilities for petroleum ink required;
• Gives brighter and cleaner colour pictures;
• Better resistance to rub-off;
• Less environmental risk because of lower emission of VOC; and
• Palm oil is readily available and renewable.

Palm colour printing ink

Printed materials with palm inks
AGROCHEMICALS

The global agrochemicals market is huge, with a host of different chemicals for various applications. However, the formulations are more limited, such as aqueous concentrate (AC), emulsifiable concentrate (EC), wettable powder (WP), suspension concentrate (SC), emulsion-in-water concentrate (EW), suspo-emulsion, water dispersible granule (WDG), etc.

There are two main components in a pesticide - active and inert ingredients. The former confers the activity, e.g., kills weeds/insects. The inert ingredients enhances the performance of the active ingredient, e.g., surfactants, emulsifiers, although the bulk is just filler to make up the product volume.

There is now a shift in pesticide formulations - EC > EW, WP > WDG and powder/ dust >SC - for greater safety and convenience in use. Flammable or toxic solvents are dispensed with, as also bulky and dusty products. Other factors, such as ease of measure and safer and more convenient disposal of the packing materials, are also increasingly important.

At present, most of the ingredients in pesticides are petroleum-based, but the general truism is what petrochemicals can do, oleochemicals can also do, although with some R&D plied in. Already, oleochemical surfactants, solvents and other derivatives are available as substitutes for the petroleum products.

Adjuvants

These are surfactants that improve the physical and chemical properties of the active ingredient. A surfactant reduces the interfacial tension between the various ingredients, and increases the solubility of the active ingredient in the formulation. The reduced interfacial tension also facilitates the formation of smaller droplets when the pesticide is sprayed, which will improve the surface coverage of the spray, allowing less chemical to be used.

On the crop, the surfactant reduces the tension between the leaf surface and water (in which the active ingredient is dissolved), enhancing the spreading and wetting of the pesticide. Tiny pesticide droplets with high surface area cover the leaf better, ensuring that more of the active ingredient is held by the target. In addition, the oil and hydrophobicity of the surfactant reduce evaporation of the spray, allowing a longer time for the active ingredient to penetrate the leaf surface.
Example inert palm ingredients for pesticide

Emulsion-in-Water (EW) Insecticides

EW formulations offer many advantages over the conventional EC formulations. Using water instead of EC is less hazardous to the operator, e.g., less skin and eye irritation. They are also less phytotoxic and water-soluble surfactants can be used. The production cost of EW is also comparable or lower, i.e., 70 - 80% of EC.

The physical properties of palm solvents and mineral oils are shown in Table 35. The viscosity and surface tension of both are comparable, but the higher flash points of the former make them less flammable. However, both possess good solvency for pyrethroid insecticides.

**TABLE 35. PHYSICAL PROPERTIES OF PALM SOLVENTS AND MINERAL OILS**

<table>
<thead>
<tr>
<th>Palm solvent/ Mineral oil</th>
<th>Physical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Viscosity (cP, 25°C)</td>
</tr>
<tr>
<td>POMEs 1ᵃ</td>
<td>9.7</td>
</tr>
<tr>
<td>POMEs 2ᵇ</td>
<td>5.3</td>
</tr>
<tr>
<td>POMEs 3ᶜ</td>
<td>5.6</td>
</tr>
<tr>
<td>POME 4ᵈ</td>
<td>3.4</td>
</tr>
<tr>
<td>Solvesso 150ᵉ</td>
<td>1.3</td>
</tr>
<tr>
<td>Xylene ᵃ</td>
<td>0.74</td>
</tr>
</tbody>
</table>

Note: a, b, c, d are palm methyl esters (POMEs), and e and f mineral oils; cP = centipoise; MN m⁻¹ = millinewton per meter.
An EW insecticide is prepared by adding an oily phase containing blended emulsifiers, (palm) solvent and active ingredients into an aqueous phase containing water and a stabilizer/thickener. The mixture is emulsified using a homogenizer of high shearing rate. Accelerated tests have shown that the product is stable after one month at 45°C and over a year at ambient. In addition, the emulsification spontaneity and emulsion stability of EW-insecticides have been compared to those of conventional EC-insecticides, with the former showing faster formation of emulsion and better homogeneity of the diluted emulsions. The optimum concentrations for blended emulsifiers, palm solvents and stabilizer/thickener are 3 - 5%, 10 - 20% and 0.3 - 0.5% (w/w), respectively. The concentration of active ingredient is 2.5 - 10% (w/w). The estimated cost of raw materials for preparing EW insecticide is comparable or slightly less than that for a conventional EC-insecticide (Table 36).

**TABLE 36. CONTENTS AND COST OF INGREDIENTS FOR PREPARING EW AND EC INSECTICIDES**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>EW Insecticide, % w/w (RM)*</th>
<th>EC Insecticide, % w/w (RM)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Solvent</td>
<td>10 - 20</td>
<td>80 - 87.5</td>
</tr>
<tr>
<td></td>
<td>(0.45 - 0.90)</td>
<td>(2.00 - 2.19)</td>
</tr>
<tr>
<td>2. Emulsifier</td>
<td>3 - 5</td>
<td>10 - 15</td>
</tr>
<tr>
<td></td>
<td>(0.17 - 0.28)</td>
<td>(0.55 - 0.83)</td>
</tr>
<tr>
<td>3. Active ingredient</td>
<td>2.5 - 5</td>
<td>2.5 - 5</td>
</tr>
<tr>
<td></td>
<td>(1.25 - 2.50)</td>
<td>(1.25 - 2.50)</td>
</tr>
<tr>
<td>4. Thickener</td>
<td>0.3 - 0.4</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>(0.90 - 1.20)</td>
<td></td>
</tr>
<tr>
<td>5. Water</td>
<td>70 - 80</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>(0.35 - 0.42)</td>
<td></td>
</tr>
<tr>
<td>Total cost per kg insecticide (RM)</td>
<td>3.12 - 5.30</td>
<td>3.80 - 5.52</td>
</tr>
</tbody>
</table>

* Figures in brackets are the cost in RM of ingredient.

EW insecticides with inert palm ingredients
Bio-efficacy tests (Table 37) on major tropical insect pests in the laboratory have shown that EW-cypermethrin has a comparable kill to ATTACT 5R, a commercial EC-insecticide. The application of an EW-insecticide on vegetables is shown below.

**TABLE 37. EFFECT OF EC-ATTACT 5R AND EW-CYPERMETHRIN (5% WT.) AGAINST MAJOR TROPICAL INSECT PESTS UNDER LABORATORY CONDITIONS AT HENKEL, PHILLIPINES (72 HOURS AFTER TREATMENT)**

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Conc. (mg/kg)</th>
<th>Insect Pest</th>
<th>Nephni</th>
<th>Nephnim</th>
<th>Nilalu</th>
<th>Sogafu</th>
<th>Mites</th>
<th>Anapco</th>
<th>(% mortality)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATTACT 5R (EC)</td>
<td>30</td>
<td>50</td>
<td>70</td>
<td>30</td>
<td>20</td>
<td>0</td>
<td>60</td>
<td>60</td>
<td>72 hours after treatment</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>100</td>
<td>80</td>
<td>70</td>
<td>40</td>
<td>0</td>
<td>90</td>
<td>90</td>
<td>72 hours after treatment</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>86</td>
<td>100</td>
<td>100</td>
<td>72 hours after treatment</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>93</td>
<td>100</td>
<td>100</td>
<td>72 hours after treatment</td>
</tr>
<tr>
<td>Cypermethrin 5% (EW)</td>
<td>30</td>
<td>70</td>
<td>100</td>
<td>50</td>
<td>30</td>
<td>0</td>
<td>50</td>
<td>50</td>
<td>72 hours after treatment</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>80</td>
<td>80</td>
<td>72 hours after treatment</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>60</td>
<td>100</td>
<td>100</td>
<td>72 hours after treatment</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>96</td>
<td>100</td>
<td>100</td>
<td>72 hours after treatment</td>
</tr>
</tbody>
</table>

**Note:**
- Nephni = *N. nigropictus*
- Nephnim = *N. virescens*
- Nilalu = *N. lugens*
- Sogafu = *S. furcifera*
- Mites = *T. kanzawai*
- Anapco = orchid thrips
Glyphosate Herbicides

The performance of palm surfactants, such as alkyl polyglycosides, alkyl alcohol ethoxylates and mixed non-ionic surfactants, in glyphosate herbicides has been studied. Glyphosate (active ingredient) is effective on deep-rooted perennial, biennial and annual grasses, sedges and broad leaves. Small-scale spraying efficacy tests of glyphosate solutions containing 0.12 - 0.22% palm surfactants show comparable performance in controlling weeds to Roundup and Sentry (commercial glyphosate herbicides), but more effective than glyphosate itself (Figure 30).

Figure 20. Effects of surfactants on bioefficacy of glyphosate isopropylamine on Cyperus rotundus (under full sunlight). Surf-1, Surf-2 and Surf-3 denote glyphosate solution containing surfactant 1, mixed-surfactants 2 and surfactant 3, respectively.
Microemulsions

Microemulsions are normally isotropic (clear) liquid mixtures of water, oil and surfactant with very small droplets (~10 – 100 nm), low viscosity and are thermodynamically stable. These properties have engendered much interest to produce high value products. In addition, there is growing interest to replace petroleum ingredients with natural materials, such as long and medium chain alkyl triglycerides and alkyl esters, in microemulsions because of their many advantages described above. Palm microemulsions containing natural insect repellents have potential applications in personal care products, air fresheners, all-purpose liquid cleaners and micro-spray insecticides for the home, garden, animal house, etc. Furthermore, microemulsion-aerosol insecticides were first developed using palm materials as the inert ingredients for public health. Bioefficacy tests have determined that palm aerosol insecticides have comparable performance to conventional aerosol insecticides.
POLYOLS AND POLYURETHANES

Palm oil and palm oil products can be converted to polyalcohols, commonly referred to as polyols in the polyurethane (PU) industry. Palm polyols (POP) are made by epoxidizing the raw material followed by reaction with short-chain alcohols, as follows:

![Epoxidation and Alcoholysis Diagram]

The polyols, which usually have two or more hydroxyl groups, are essential ingredients in PU products. The other major ingredient is isocyanate, either toluene diisocyanate (TDI) or methylene diisocyanate (MDI). A typical PU recipe is a polyol, an isocyanate, surfactants, catalysts (to accelerate gelling and blowing), cross-linkers, and water (as blowing agent).

Depending on the formulation, three types of PU foam - rigid, semi-rigid and flexible - can be obtained for furniture, mattresses, construction materials, etc. MPOB has formulated some PU products with potential in various industries (Table 38).

<table>
<thead>
<tr>
<th>Product</th>
<th>Properties/Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Flora Foam</td>
<td>Good gripping/penetration with suitable density</td>
</tr>
<tr>
<td>Thermal Insulator</td>
<td>Insulation for freezer – trials indicate comparable performance with petroleum materials</td>
</tr>
<tr>
<td>Flexible PU</td>
<td>With lazy foam characteristics, suitable for furniture industry (cushions and bedding materials). Flexible for moulding into automotive components</td>
</tr>
<tr>
<td>2K PU Adhesives</td>
<td>Potential as binder for MDF boards</td>
</tr>
<tr>
<td>2K PU Coatings</td>
<td>Potential in wood-based industry, such as for furniture, buildings, decorative items.</td>
</tr>
<tr>
<td>PU Sheet</td>
<td>Potential in furniture, handbags</td>
</tr>
<tr>
<td>PU Coated Fertilizer</td>
<td>Slow-release fertilizer</td>
</tr>
<tr>
<td>PU Ornamental</td>
<td>Potential as home decor, interior and exterior</td>
</tr>
<tr>
<td>PU Pergola</td>
<td>Landscaping</td>
</tr>
</tbody>
</table>

TABLE 38. PU PRODUCTS BY MPOB
Example Polyurethane Products

Thermal Insulation  'Lazy’ foam

PU ornamental products  Construction materials (walls and roof)

Flexible foam  PU pergola
CANDLES

Candles are today used in religious ceremonies, at home and in restaurants, for their ambiance, and to warm food. Many types are available: columns, pillars, tapers, votives, wax-filled containers, etc.

Candles can be made by dipping, extruding or moulding, but factory production relies mainly on the last two processes.

Simple as a candle appears, its performance involves many factors, one of the most important being the raw materials used. Traditionally, beeswax and solid fats were used. However, the latter has always been objectionable because pyrolysis of the fats produces acrolein, a pungent and eye-watering chemical, and stench. Beeswax is expensive, ever increasingly so. With the development of fat splitting, replacement of the solid fats by fatty acids has eliminated the acrolein problem and improved the other candle properties. With the increase in petroleum production, paraffin wax, a by-product from its refining, has become the most important wax for candles, mainly because of price. However, it has several major drawbacks because of its wide melting point range. Also, it produces smoke and sags easily in hot climates. And its colour is dull, but yet does not dissolve dyes readily to overcome the problem, and exhibits poor contraction, making de-moulding difficult.

One way to overcome the problems is to incorporate stearic acid, a superb raw material for candle making. It is hard, has high contraction, disperses dyes easily, reflects light very well and imparts good lustre and opacity to the product. In the 1970s, when stearic acid was much more expensive than paraffin wax, it was added to candles at about 10 - 20%. But, now, it is often cheaper than paraffin wax.

Commercial stearic acid for candle making is really a mixture of palmitic and stearic acids, a major source of which is palm oil. Double- or triple-pressed grade acid with a titre of 53°C and good colour is highly suitable. Other palm materials, such as palm stearin, have also been used for fragrant candles.

In the manufacture of candles by de-moulding, high contraction (shrinkage) of the stearic acid/paraffin wax blend is important. With palm oil stearic acid, the contraction is highest at the approximate ratio of 70/30 stearic/paraffin wax.

Decorative candles
LUBRICANTS

Lubricants normally refer to products used for the lubrication of sliding or rolling elements. Other products, such as power and heat transmission media, dielectrics and process oils, are also considered lubricants. Lubricants can be classified into two major categories - automotive and industrial. Automotive lubricants comprise all types of engine oils while industrial lubricants are those used in industrial applications. Examples of industrial lubricants are hydraulic fluid, gear oil and drilling mud and grease.

Natural triglycerides and wax esters have been used as lubricants for thousands of years while the dominant role of mineral oil in lubricants is only but a century old. Oils and fats commonly used in lubricants include tallow, lard and soybean, castor and palm kernel oils. The wax esters, used currently and in the past, includes sperm whale oil, jojoba oil and orange roughy oil (from marine fish).

Vegetable oils offer significant environmental advantages with their renewability, biodegradability and adequate performance in a variety of applications. They are particularly suited for total loss lubricants, such as two-stroke engine oil and lubricants for farming and mining.

Vegetable oils (unmodified or unformulated) are susceptible to degradation from oxidation and hydrolysis. To improve their oxidative and hydrolytic stability as well as low temperature properties, they can be converted to esters. Typical examples include monoesters, such as butyl stearate and 2-ethylhexyl palmitate, and dibasic esters, such as di-isodecyl adipate and di-octyl sebacate.

Palm oil and the esters from it possess desirable properties, such as good adhesion to metal, good lubricity and strong oxidative stability, and are suitable base fluids for various lubricants, such as hydraulic fluids and greases. As base oil, palm oil, can be used to produce biodegradable food grade lubricants.

Palm hydraulic fluid
Polyurethane coatings have broad application, as they possess excellent adhesion, abrasion resistance and weather resistance with a satisfactory balance between the film elasticity and hardness. In general, the coatings are found in automotive, wood, masonry, concrete, plastic and rubber products.

Palm oil derivatives, such as oleic acid, have unsaturated sites that can be manipulated chemically to yield the functionality for certain applications. MPOB has converted oleic acid with glycerol into a polyl (PolyMO) that can be further converted to polyester polyl (PolyMO ester), one of the main ingredients for two-pack polyurethane (2K-PU) coating. The polyester polyl has hydroxyl functionality and can be reacted with a hardener, such as diisocyanate, to form polyurethane coating.

The palm polyester polyl has been formulated into indoor and outdoor polyurethane coatings for wood. Performance of the 2K-PU coatings was tested to DIN 68861 and fulfilled all the requirements. In addition, the coatings exhibited satisfactory results from artificial weathering with exposure to UV radiation according to test method DIN EN 927-62.

From a technical point of view, palm polyurethane coatings satisfy the industrial requirements. Moreover, being from renewable and sustainable resources, they have economical and environmental advantages over petroleum materials, making them an attractive alternative.

---

1. DIN 68861 Furniture Surfaces Test
2. DIN EN 927 Paints and Varnishes – Coating materials and coating systems for exterior wood – Part 6: Exposure of wood coatings to artificial weathering using fluorescent UV light and water.
MPOB has developed polyols from palm oil through epoxidation and alcoholysis. The polyols can be reacted with diisocyanates to give a variety of polyurethane (PU) products. One of the polyols, PolyEG, has found applications as building materials and automotive parts.

Furthermore, PolyEG can also be blended with a new polyol from palm oil, PolyMO, and then reacted with a suitable isocyanate to produce an adhesive for wood-based application that conforms to DIN EN 2053 standard.

One of the potential applications for palm adhesive is in medium density fibreboard (MDF), in which the adhesive acts as a binder for the fibre. MDF boards with palm adhesive were found to meet all the industrial requirements.

Palm 2K PU adhesive can be an alternative to the current adhesives as its performance satisfies the industry expectations, and is made from renewable resources.

SPECIALTY CHEMICALS

PALM DIHYDROXYSTEARIC ACID (DHSA) AND DERIVATIVES

DHSA from oleic acid is a specialty chemical with a unique structure. It has a carboxyl group and two hydroxyl groups at the 9- and 10-positions of the C18 chain. Therefore, it can greatly modify the properties of oily phases and wax gels, and also interacts strongly with the solid surfaces of pigments and inorganic fillers, leading to better colour development and long skin adhesion. Such structure leads to many interesting applications, particularly in cosmetics.

Structure of 9, 10-dihydroxystearic acid

Samples of 9, 10-dihydroxy stearic acid
DHSA is compatible with the ingredients in cosmetics. Its hydrophobicity allows its use in coloured cosmetics and as a coating agent for pigments. Coloured cosmetics products include compact powder, lipstick and eye shadow.

Compact powder, lipstick, foundation and mascara from DHSA/DHSA derivatives

As an additive in transparent soap, DHSA enhances the transparency (Figure 23).

Transparent soap without DHSA

Transparent soap with DHSA
DHSA is compatible with the ingredients in cosmetics. Its hydrophobicity allows its use in coloured cosmetics and as a coating agent for pigments. Coloured cosmetics products include compact powder, lipstick and eye shadow.

Besides cosmetics, DHSA can also be a component in polyl for the production of low-density open-cell rigid polyurethane foam for making flower foam and packaging material.

Figure 21. Transparency index of soap without DHSA or 12 hydroxystearic acid (12HSA), with crude CDHSA and purified dihydroxystearic acid (PDHSA).

Low-density ‘open-cell rigid polyurethane foam’ from DHSA
DHSA is also a potential feedstock for various derivatives through substitution onto one, two or all three of its reactive sites. Some alkyl esters from DHSA, e.g., octyl DHSA, have conferred exceptional skin feel and powder binding capability. Metallic soaps of DHSA have shown pigment coating capability and different properties from the usual metallic stearates. Many more derivatives, such as estolides, alkanoamide, ethoxylates, have been derived from DHSA to exploit its derivatisation potential. Some reactions for DHSA derivatives are shown below:

**Octyl DHSA**

![Esterification between DHSA and Octanol to produce Octyl DHSA](image)

**DHSA Estolides**

![Condensation of DHSA to produce DHSA estolide](image)
DHSA Alkanolamide

\[
\text{DHSA} + \text{NH}_2\text{CH}_2\text{CH}_2\text{OH} \rightarrow \text{DHSA Alkanolamide}
\]

DHSA Ethoxylates

\[
\text{DHSA} + n\text{CH}_2\text{CH}_2\text{O} + \text{Basic or acid catalyst} \rightarrow \text{DHSA Ethoxylates}
\]

PALM DIESEL

Petroleum is a depleting resource and burning it as fuel (particularly diesel) releases large quantities of greenhouse gases and sulphur compounds, contributing to global warming and acid rain. These concerns have prompted the development of renewable fuels, and bio-ethanol and bio-diesel are the two in the fore currently.

Vegetable oils with low free fatty acids (<1%) can easily be converted to biodiesel (chemically, fatty acid methyl esters) through transesterification with methyl alcohol and an alkaline catalyst, \textit{viz}.

\[
\begin{align*}
\text{Triglyceride} & \quad \text{Catalyst} \quad \text{Alcohol} \quad \text{Esters} \quad \text{Glycerol} \\
\text{CH}_2\text{OCOR}_1 & + 3\text{R'OH} \quad & \quad \text{R}_1\text{-COOR'} & + \quad \text{CH}_2\text{OH} \\
\text{CHOCOR}_2 & & \text{R}_2\text{-COOR'} & + \quad \text{CHOH} \\
\text{CH}_2\text{OCOR}_3 & & \text{R}_3\text{-COOR'} & + \quad \text{CH}_2\text{OH}
\end{align*}
\]
MPOB (then PORIM) has investigated palm biodiesel from the early 1980’s, and has a 3,000 tonnes/year pilot plant (with PETRONAS) to produce samples for trial. Both MPOB and PETRONAS together have also patented a process for converting palm oil to biodiesel.

Field trials have yielded many positive results, *inter alia*, 1) no dark smoke, 2) marked reduction in carbon monoxide, 3) no modification of engine needed, and 4) marked reduction in particulate emission.

Due mainly to environmental concern, the global demand for biodiesel has increased by leaps and bounds. Committed to the promotion of renewable energy, MPOB, in 2005, licensed its technology to two engineering firms and financed the construction of three 60,000 tonnes/year commercial plants using its technology. Since then, nine palm biodiesel plants have been constructed with capacities from 60,000 to 120,000 tonnes/year, five in Malaysia, two in Thailand and one each in Colombia and Korea. The palm biodiesel produced meets stringent International specifications, namely, ASTM D6751 and EN14214 (Table 39). Malaysian palm biodiesel produced is used locally and exported, mainly to EU countries.

MPOB has also developed a winter grade (low pour point) palm biodiesel, and financed three commercial plants to process 30,000 tonnes/year each of normal palm biodiesel into the winter grade.

Malaysia formulated a biofuel policy in 2006 to encourage the use of palm biodiesel. It aims to reduce its dependence on fossil fuels, while promoting the demand for palm oil to help stabilize its price.
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---

**Table 39: Fuel Properties Of Normal And Low Pour Point Palm Biodiesel**

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Normal Biodiesel</th>
<th>Low Pour Point Biodiesel</th>
<th>EN 14214</th>
<th>ASTM D6751</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ester content</td>
<td>% mass</td>
<td>98.5</td>
<td>98.0 – 99.5</td>
<td>96.5 (min.)</td>
<td>-</td>
</tr>
<tr>
<td>Density at 15°C</td>
<td>kg/ L</td>
<td>0.8783</td>
<td>0.87 – 0.89</td>
<td>0.86 – 0.90</td>
<td>-</td>
</tr>
<tr>
<td>Viscosity at 40°C</td>
<td>mm²/s</td>
<td>4.415</td>
<td>4 – 5</td>
<td>3.5 5.0</td>
<td>1.9 – 6.0</td>
</tr>
<tr>
<td>Flash point</td>
<td>°C</td>
<td>182</td>
<td>150 – 200</td>
<td>120 (min.)</td>
<td>130 (min.)</td>
</tr>
<tr>
<td>Cloud point</td>
<td>°C</td>
<td>15.2</td>
<td>-18 – 0</td>
<td>-</td>
<td>Report</td>
</tr>
<tr>
<td>Pour point</td>
<td>°C</td>
<td>15</td>
<td>-21 – 0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cold filter plugging point</td>
<td>°C</td>
<td>15</td>
<td>-18 – 3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulphur content</td>
<td>% mass</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001 (max.)</td>
<td>0.0015 (max.) Grade S15</td>
</tr>
<tr>
<td>Carbon residue (on 10% distillation residue)</td>
<td>% mass</td>
<td>0.02</td>
<td>0.02 – 0.03</td>
<td>0.3 (max.)</td>
<td>0.05 (max.)</td>
</tr>
<tr>
<td>Acid value</td>
<td>mg KOH/g</td>
<td>0.08</td>
<td>&lt;0.3</td>
<td>0.5 (max.)</td>
<td>0.8 (max.)</td>
</tr>
<tr>
<td>Sulphated ash content</td>
<td>% mass</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>0.02 (max.)</td>
<td>0.02 (max.)</td>
</tr>
<tr>
<td>Basic sediment and water</td>
<td>% mass</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>0.05 (max.)</td>
<td>0.05 (max.)</td>
</tr>
<tr>
<td>Cetane number</td>
<td>-</td>
<td>58.3</td>
<td>53.0 – 59.0</td>
<td>51 (min.)</td>
<td>47 (min.)</td>
</tr>
<tr>
<td>Copper strip corrosion (3h at 50°C)</td>
<td>Rating</td>
<td>1a</td>
<td>1a</td>
<td>1</td>
<td>3 (max.)</td>
</tr>
<tr>
<td>Iodine value</td>
<td>-</td>
<td>52</td>
<td>56 – 83</td>
<td>120 (max.)</td>
<td></td>
</tr>
<tr>
<td>Linolenic acid methyl ester</td>
<td>% mass</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>12 (max.)</td>
<td></td>
</tr>
<tr>
<td>Polysaturated ethyl esters (≥3 double bonds)</td>
<td>% mass</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>1 (max.)</td>
<td></td>
</tr>
<tr>
<td>Methanol content</td>
<td>% mass</td>
<td>&lt;0.2</td>
<td>&lt;0.2</td>
<td>0.2 (max.)</td>
<td>-</td>
</tr>
<tr>
<td>Monoglyceride content</td>
<td>% mass</td>
<td>&lt;0.4</td>
<td>&lt;0.4</td>
<td>0.8 (max.)</td>
<td>-</td>
</tr>
<tr>
<td>Diglyceride content</td>
<td>% mass</td>
<td>&lt;0.2</td>
<td>&lt;0.2</td>
<td>0.2 (max.)</td>
<td>-</td>
</tr>
<tr>
<td>Triglyceride content</td>
<td>% mass</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>0.2 (max.)</td>
<td>-</td>
</tr>
<tr>
<td>Free glycerol</td>
<td>% mass</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.02 (max.)</td>
<td>0.02 (max.)</td>
</tr>
<tr>
<td>Total glycerol</td>
<td>% mass</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.25 (max.)</td>
<td>0.24 (max.)</td>
</tr>
<tr>
<td>Phosphorus content</td>
<td>mg/kg</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>10.0 (max.)</td>
<td>-</td>
</tr>
<tr>
<td>Group I metals (Na+K)</td>
<td>mg/kg</td>
<td>3.1</td>
<td>3.1</td>
<td>5.0 (max.)</td>
<td>-</td>
</tr>
<tr>
<td>Group II metals (Ca+Mg)</td>
<td>mg/kg</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>5.0 (max.)</td>
<td>-</td>
</tr>
</tbody>
</table>

**Notes:** ASTM D6751: American Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels

EN14214: European Standard for Biodiesel
National Biodiesel Programme

In 2009, MPOB field tested B5 (biodiesel with 5% palm methyl esters and 95% petroleum diesel) on 3,900 vehicles belonging to government agencies, such as DBKL and the Armed Forces. With no technical problems reported, the coast was clear to implement the national biodiesel programme in June 2011. This was to support the palm oil price by creating local demand for it in biodiesel. The MPOB B5 working group was established to spearhead the programme. The scope of the WG included meeting with stakeholders and government agencies to iron out biodiesel issues, further investigating biodiesel, such as testing B5 with Lembaga Kemajuan Ikan Malaysia (LKIM) for fishing boats, and preparing Cabinet papers for biodiesel implementation. To-date, 35 blending facilities have been set up at petroleum depots in Malaysia to produce biodiesel. The B5 programme has been successfully implemented in Peninsular Malaysia since March 2014, and the palm oil content nudged up from 5% to 7%, i.e. B5 to B7, in November 2014 after agreement with all stakeholders. Biodiesel was extended to East Malaysia in December 2014. The launching of B7 in Sarawak, Sabah and WP Labuan was held successfully in Bintulu, Sarawak on 17 January 2015.

The implementation of B7 nationwide uses 575,000 tonnes of palm oil a year, which will help reduce palm oil stock and strengthen its price. For every RM100 increase in the palm oil price, the nation will earn an additional RM2 billion a year in revenue. The biodiesel programme also benefits the country by creating jobs from direct and indirect employment in its related activities, e.g., transport of the fuel, engineering services, etc.
Launching of B5 for Eastern Region of Peninsular Malaysia and completion of B5 implementation in Peninsular Malaysia by YAB Chief Minister of Pahang and YB Minister of Plantation Industries and Commodities in March 2014

Launching of B7 for Sarawak, Sabah and Labuan by YB Minister of Plantation Industries and Commodities in January 2015
CHAPTER 5:
OIL PALM BIOMASS
INTRODUCTION

Biomass is a sustainable resource for the furniture, pulp and paper industries and energy. It is increasingly used due to global concern over the environment. The palm oil industry generates almost 94% of the biomass in Malaysia.

The estimated production of oil palm biomass in 2015 was about 90 million tonnes (dry weight). There has been encouraging increasing use of the biomass, although yet mainly for low value products, like compost/mulch and fertilizer. But, it is nudging into higher-value uses, like medium density fibreboard and plywood. The oil palm trunk contains lignin (18 - 22%), cellulose (38 – 45%) and hemicellulose 33 – 42%), each of which has potential uses.

OIL PALM BIOMASS

The estimation of biomass produced by the oil palm industry is fraught with difficulty, the different methods used giving different answers. Of the dry biomass produced from processing oil palm fruits, 21-22% is empty fruit bunch (EFB), 12-16% mesocarp fibre (MF) and 5-7% palm kernel shell. Other biomass from the mill are decanter solids and palm oil mill effluent (POME) treatment sludge, but only in small amounts. Meanwhile, the plantation produces oil palm trunk (OPT) and oil palm fronds (OPF). OPF is available during harvesting and scheduled pruning and also with OPT during replanting when the old crop is felled at 25 – 30 years old.

COMMERCIALIZATION

There have been much R&D into using oil palm biomass. Some products have already been commercialized and some showing potential.

Palm Plywood/Veneer

Plywood can be made from OPT. The log is cut by a rotary lathe into veneer. Several layers of veneer are then glued together cross-grained, the number of layers depending on how thick the plywood is to be. MPOB has collaborated with the wood industry to produce palm plywood complying with the JAS 233:2003 standard (Table 40).

<table>
<thead>
<tr>
<th>TABLE 40. STRENGTH PROPERTIES OF PALM PLYWOOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Direction: Perpendicular to grain</td>
</tr>
<tr>
<td>Bending Strength, MPa</td>
</tr>
<tr>
<td>9 mm thick</td>
</tr>
<tr>
<td>15 mm thick</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>33.5</td>
</tr>
<tr>
<td>37.0</td>
</tr>
<tr>
<td>Test direction: Parallel to grain</td>
</tr>
<tr>
<td>Bending Strength, MPa</td>
</tr>
<tr>
<td>9 mm thick</td>
</tr>
<tr>
<td>15 mm thick</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>20.8</td>
</tr>
<tr>
<td>25.2</td>
</tr>
</tbody>
</table>
Fibre-reinforced plastics are mainly used for upholstery in the local automotive industry. Up to 30% EFB fibre can be incorporated in the plastics and this not only reduces the volume of (more expensive) resin used but also makes for a lighter product.

Another product is dampening sheet, included in the upholstery to absorb and reduce noise, vibration and harshness (NVH) in the moving vehicle. Damping sheets are normally made by melting one or more binders, natural/synthetic rubber and/or various synthetic resins. Fillers such as asbestos and calcium carbonate are mixed with the binder before rolling the mixture into sheets which are then cut into the desired shapes. MPOB has produced a damping sheet by substituting the asbestos, silica, recycled paper and resins with oil palm fibre and different resins. Oil palm fibre is a cheaper and more environmentally-friendly material, with no compromise on the commercial properties of the sheets. The product complies with an international standard (ES-X 62223/6 Mitsubishi Motor Corporation Test Standard) for the automotive industry.
Medium Density Fibreboard (MDF)

Medium density fibreboard (MDF) is a bio-composite made from homogeneous fibre with a density of 600 - 800 kg/m³. An essential element in the manufacture is the pressurized refiner which produces pulp of very low bulk density.

MDF from OPT and OPF has excellent strength and hygroscopic properties, with a light colour and good surface appearance. The MDF blended with up to 40% rubber and mixed tropical woods, also showed very good internal bonding and acceptable tensile strength.

Flow chart of MDF preparation.
Palm Lumber

OPT is a variable product - the wood hardness decreases from bottom of the trunk upwards, and from outside to inside. This variability increases its cost of processing and use. The fresh trunk is also extremely wet (100 - 500% moisture content), and needs dedicated facilities to dry. MPOB has developed the Multi-Profile Kiln-Drying Heating system, recovering 58% of the logs as lumber vs. only about 56% from normal drying with lower (10 – 15%) degrades - cracking, honeycombing and collapse- to boot.

![Typical drying degrades of oil palm lumber.](image)

The end product of oil palm lumber is basically for furniture such as dining tables, cupboard or chairs.

![Furniture from OPT lumber.](image)
Moulded Particleboard

The particleboard industry in Malaysia can be categorized into two, viz., panel products and furniture. The production of particleboard is shown in Figure 22. The moulded particleboard industry has huge potential due to the demand for components to manufacture furniture for offices, hospitals, etc.

Moulded Pulp Products

Interest in EFB to produce pulp for packaging continues to grow. Chemimechanical pulping is used - the EFB fibre bundles are pretreated followed by preheating, and then subject to mechanical pressure in a disc refiner. The pulping defibrillates the elementary fibre in the EFB fibre bundles.

Figure 22. Flow chart for preparation of no skin particleboard.
Eco-Pallet

An eco-pallet is a flat structure that supports stored goods while allowing easy lifting by forklift, pallet jack and other jacking devices. It comes in many forms – made from wood, plastic, metal or paper and even from EFB fibre. The manufacturing of eco-pallet from EFB uses the high pressure and temperature process, with resin bonding to inhibit fungus and pest attack. This property is desirable for the export market.

Eco-pallet from oil palm EFB.
Charcoal and Activated Carbon

Palm kernel shell is usually burnt for energy, but can be used to make charcoal or activated carbon. Lately, charcoal has gained interest in toiletries and food products. Beside the common products of charcoal tablet and wood vinegar, new products from charcoal are shampoo, soap and skin care cream.

The bottleneck in the production of activated carbon is preparation of the charcoal. For centuries now, charcoal-making systems are not environmentally-friendly. MPOB, however, has developed green carbonization processes i) Dome Kiln Carbonization, and ii) Continuous Carbonization Furnace. These new technologies are more environmentally-friendly and also produce wood vinegar as a valuable by-product.

In continuous carbonization (Process 2), the biomass is passed through a horizontal rotary kiln at 600 - 700°C. The system uses external heating burning diesel but is adaptable to natural gas or biogas. Thus, this system can be installed in the mill and use biogas generated from POME. If production of activated carbon is also intended, excess steam from the boiler can be used as the activation agent.
EMERGING TECHNOLOGIES

Some new, promising technologies are:

Compostable Plastic Film

Compostable plastic is produced by blending refined biomass powder with plastic resin. The product degrades naturally in the environment after discard. The physical and mechanical properties of such palm plastic films are comparable to those of commercial products.
Pulp and Paper

There are a number of technologies for producing pulp and paper from EFB, such as the Kraft, Kraft-Anthraquinone (AQ), chemi-thermomechanical (CTMP) and thermo-mechanical (TMP) processes. CTMP pulp from EFB has rather low brightness (30%) compared to softwood pulp from the same process. However, its strength characteristics are superior. The pulp can be used for wrapping paper or further processed to newsprint and high quality printing paper.

From OPF, the pulp is even darker (20%) but the yield slightly higher. The pulp is suitable for corrugated board and the un-bleached pulp for food packaging. Corrugated board is a paper-based construction material of a fluted corrugated sheet and one or two flat linerboards. It is widely used in the manufacture of corrugated boxes and shipping containers.

Engineered Wood

With depleting timber, alternative ‘wood’, including oil palm biomass, beckons. Already, the scenario is changing and traditional solid wood products are being made from engineered wood and plastics. Some examples of the new ‘wood’ from oil palm are:

i. Resin impregnated oil palm lumber for flooring and panels
ii. Resin impregnated veneer for laminated veneer lumber (LVL) composite
iii. High density plyboard
iv. Oriented strand board (OSB)
v. Sandwich board
In 2016, MPOB introduced a high density plyboard, for concrete formwork, joinery and furniture. The production process involves resin impregnation of OPT veneer (vacuum system), then compression to about 75% of the initial thickness using a cold press. The densified resin-treated veneer is pre-cured in an electric oven.

High-density plyboard.

Fine Chemicals

Lignocellulose is biomass of principally lignin, hemicellulose and cellulose. It can be extracted for fine chemicals (sometimes called green chemicals) via multistage extraction, pyrolysis, catalytic cracking or even bio-refining.

MPOB has a process for extracting cellulose from EFB. The cellulose, which is the basic material for production of cellulose derivatives, can be further modified into carboxymethyl cellulose (CMC) or micro-crystalline cellulose (MCC). CMC is an anionic, biodegradable and linear polymer ether. It is one of the most versatile water-soluble hydrocolloids and has a number of important properties, including solubility, rheology, adsorption on surfaces, etc. CMC has various uses in the food and non-food industries.

Figure 39. CMC from EFB fibre.
MPOB has recently introduced xylo-oligosaccharide - a fine chemical from palm hemicellulose. It is a new prebiotic product with great potential for stimulating the growth of micro flora in the gastro-intestinal tract. The process involves extraction of xylan which is then treated with xylanase enzymes immobilized in a packed bed column reactor (PBCR).

Another fine chemical - lignin- is also of interest as green bio-polymer. Lignin can be extracted and purified from the black liquor of EFB pulping. Such extraction is more economical.

*Black liquor and its conversion to lignin powder.*
CHAPTER 6:
ENERGY FROM
OIL PALM BIOMASS
Palm Lignocellulose

While oil is the main product from oil palm, it constitutes only about 10% of the total dry matter production of the palm; the remaining 90% being biomass, which is largely discarded despite its potential applications. One possibility is to generate power from it.

Palm lignocellulose consists of lignin, cellulose, hemicellulose and ash (Table 41). The cellulose and hemicellulose can be turned into liquid fuels (bioethanol, bio-oil, synthetic diesel) and the lignin into solid fuels. Lignin is a complex polymer of phenylpropane units, cross-linked to each other with a variety of different chemical bonds to give the cell walls mechanical strength. Cellulose is a long chain glucose molecule linking primarily with 1,4-glycosidic bonds. Hemicellulose occurs in bundles in the cellulosic matrix to enhance the stability of the cell wall. Hemicellulose consists of branched polymers, formed from monomers of xylose, arabinose, galactose, and mannose. It cross-links with lignin in a complex web of bonds. Cellulose and hemicellulose are made up of mostly glucose and xylose, respectively, which can be extracted for use.

**TABLE 41. CHEMICAL COMPOSITION (%) OF OIL PALM BIOMASS**

<table>
<thead>
<tr>
<th>Component (%)</th>
<th>Empty Fruit Bunch</th>
<th>Oil Palm Trunk</th>
<th>Oil Palm Frond</th>
<th>Palm Shell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignin</td>
<td>19.67 ± 6.80</td>
<td>20.51 ± 4.01</td>
<td>20.50 ± 2.20</td>
<td>50.7</td>
</tr>
<tr>
<td>Holocellulose:</td>
<td>78.00 ± 8.70</td>
<td>75.00 ± 5.02</td>
<td>80.33 ± 3.18</td>
<td>43.5</td>
</tr>
<tr>
<td>i. α-cellulose</td>
<td>46.17 ± 11.17</td>
<td>42.32 ± 5.18</td>
<td>40.10 ± 9.70</td>
<td>20.8</td>
</tr>
<tr>
<td>ii. Hemicellulose</td>
<td>32.30 ± 7.82</td>
<td>32.35 ± 1.65</td>
<td>37.05 ± 3.35</td>
<td>22.7</td>
</tr>
<tr>
<td>Ash</td>
<td>3.2 ± 2.31</td>
<td>1.6 ± 0.35</td>
<td>3.28 ± 0.87</td>
<td>4.44</td>
</tr>
</tbody>
</table>

As oil palm biomass contains energy (Table 42), its potential as fuel is obvious.
TABLE 42. POTENTIAL OF OIL PALM BIOMASS (DRY BASIS) AS FUEL
(Annual production in Malaysia)

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Total Annual Production (million tonnes)</th>
<th>Gross Calorific Value (Mj/kg)</th>
<th>Energy Potential (million, barrels oil equivalent)</th>
<th>Energy Potential (pJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empty fruit bunch</td>
<td>7.3</td>
<td>18.88 ± 0.74</td>
<td>22.7</td>
<td>138.6</td>
</tr>
<tr>
<td>Mesocarp fibre</td>
<td>7.7</td>
<td>19.06 ± 0.32</td>
<td>24.1</td>
<td>147.1</td>
</tr>
<tr>
<td>Palm shell</td>
<td>4.5</td>
<td>20.09 ± 0.43</td>
<td>14.7</td>
<td>89.6</td>
</tr>
<tr>
<td>Oil palm frond</td>
<td>21.7*</td>
<td>15.72 ± 0.26</td>
<td>56.0</td>
<td>341.6</td>
</tr>
<tr>
<td>Oil palm trunk</td>
<td>3.6*</td>
<td>17.47 ± 0.35</td>
<td>10.3</td>
<td>62.9</td>
</tr>
<tr>
<td>Palm oil mill effluent (POME)</td>
<td>3.2**</td>
<td>16.99 ± 0.58</td>
<td>8.9</td>
<td>54.4</td>
</tr>
</tbody>
</table>

* Computed based on 50% availability from total biomass generated in the field
** Computed based on 5% dry solids in POME

**Palm Briquettes**

Before oil palm biomass can be used as a fuel, it has to be processed for practicality, e.g., reduce its size and moisture content for easier handling. EFB, in loose fibrous form, is the easiest to process – by briquetting and pelleting to densify it. It can be further processed to charcoal or torrefied pellets/briquettes. Binderless briquettes can be produced using a screw extrusion or piston press. In screw extrusion, the biomass is forced through a taper die heated externally. Alternatively, a piston presses the biomass with very high pressure but at moderate temperature. No binder is required as the lignin is fluidized in the process to bind the fibre.
Production of palm briquettes.

Bio-Oil/Bio-Char

Palm biomass can be pyrolysed in a quartz fluidized-fixed bed reactor or Bio-char Experimental Kit (BEK) at 300 - 700°C to produce bio-oil, bio-char and gas.

Bio-oil has a calorific value of 16 - 23 MJ/kg. It is a dark brown, free-flowing liquid of highly oxygenated compounds with functional groups, such as phenols, alcohols, ketones, aldehydes and carboxylic acids. The commercial applications include producing food flavoring and fine chemicals, and as a fuel for small engines and boilers.

Bio-char can be made into a solid fuel, such as briquettes, or mixed with oil and water to become char-oil or char-water slurries with high calorific values. Besides, it is also a suitable feedstock for activated carbon and soil enhancer.

Bioethanol

To produce ethanol from palm lignocellulose, a pre-treatment of chemical and enzymatic hydrolysis is needed. As lignocellulose forms the cell walls of a strongly bonded matrix, pre-treatment is required to break down the structure to release the sugars contained therein for fermentation.

EFB and OPT are the two palm lignocellulosic materials currently used for bioethanol production. So far, the most practical way is to soak pulverized EFB in 1% NaOH followed by hydrolysis with 0.7% sulphuric acid and an enzyme to release the sugars which are then fermented with *Saccharomyces cerevisiae*. So far, ~10.5 g bio-ethanol can be produced from 50 g EFB after 72 hours’ incubation. On the other hand, the juice or sap of OPT can be directly fermented to bioethanol without need for pre-treatment.
Bioethanol from palm empty fruit bunches and trunks.

The bioethanol produced can be used as a fuel or solvent, while the recovered lignin converted to various useful derivatives e.g., surfactants for enhanced oil recovery. However, there remain huge challenges in using palm lignocellulose as biofuel as the current technologies have yet to produce satisfactory yields.

Biogas

Palm oil mill effluent (POME) has a high organic content (BOD of 18 225 - 23 904 ppm, COD of 45 818 - 54 861 ppm). By decomposing the organic matter anaerobically, biogas is produced with 60 - 70% methane (CH₄), 30 - 40% carbon dioxide (CO₂) and trace hydrogen sulphide (H₂S). An estimated volume of 1776 million m³/year biogas can be produced from all the POME generated in the country. A potential 16 - 20 million tonnes of CO₂ eq/year can be mitigated if all palm oil mills capture the biogas.

The biogas captured can be used as fuel – to generate electricity and/or produce steam and heat or even for vehicles and cooking. MPOB and two companies have jointly developed different systems to generate biogas from POME, focusing on the effluent discharge quality, biogas characteristics and zero discharge. Several plants have been built - at Tee Teh Palm Oil Mill, Rompin, Pahang and Ladang Sabah Palm Oil Mill, and the MPOB Experimental Palm Oil Mill (POMTEC) at Labu, Negeri Sembilan.
BEE high efficiency methane fermentation system.

Palm oil mill effluent zero discharge treatment system.
Producer Gas

Oil palm biomass can be gassified. MPOB has developed a technology (pilot plant with compartmented fluidized-bed) to produce producer gas from EFB and palm shell. EFB in its dry and pulverized form is fed into the system at 700 - 1000°C to yield producer gas of H₂, CO and CH₄ with approximate concentrations of 10.9%, 18.5% and 3.4%, respectively, and heating value of 5.2 MJ/Nm³.
CHAPTER 7:
ANIMAL FEED FROM OIL PALM BIOMASS
The oil palm plantation, mill, crushing plant and refinery produce various by-products, some of which are suitable as animal feed - for ruminants (cattle, sheep) as well as monogastric animals (chicken, pigs).

**From the Plantation**

Palm fronds, can be fermented into silage for cattle. Leaf pellets can also be produced, providing quality fibre and vitamin E for horses.

**From the Oil Palm Mill**

Palm oil is already incorporated in poultry and pig rations (at 5 – 10%). The oil is mainly to increase the energy content of the feed, but its oiliness also minimizes dustiness. It also contains significant amounts of nutrients, like carotenes and tocopherols/tocotrienols (vitamin E), which may contribute to the animal health but certainly improves the storability of the feed. The carotenes also enhance the skin colour of broiler chicken.

Sludge oil is a by-product from cleaning and desludging the mill. However, it is not always available, being only produced in small volumes.

Other products, like palm pressed fibre (PPF), are plentiful but less suitable as animal feed due to their low protein and high lignin contents. Similarly for EFB, which can be used for mushroom culture, after which it has better feeding value for cattle as the residual mushroom bodies in it increase its protein content and quality.
From the Palm Kernel Crushing Plant

Two ingredients are available - palm kernel pellets (PKP) and palm kernel cake (PKC). They are similar products, except that the former is the residue after solvent extraction of the kernel oil, and the latter from mechanical screw-pressing. The oil content in PKP is 3% and in PKC 6-10% to as high as 15%. Crushing is less efficient in oil extraction than solvent, so leaves more oil in PKC. Both the pellets and cake have a similar composition to alfalfa, and are suitable feeds for cattle.

PKC and PKP are the most abundant animal feed from the Malaysian oil palm industry, and are mainly exported to Europe where they are standard ingredients in dairy rations. In Vietnam, they are used for pigs and poultry.
From Oil Refining

PFAD, palm acid oil and palm kernel fatty acid distillate (PKFAD) are by-products from the refinery. The latter is less available as less PKO is produced than PO and, furthermore, crude PKO contains less FFA than CPO.

Three feed products are available from PFAD - raw PFAD (RPFAD), its calcium soap (CSPFAD) and hydrogenated PFAD (HPFAD). RPFAD is an excellent source of energy in cattle and poultry rations. It is sprayed directly on the feed pellets as they come out from the extruder.

CSPFAD is a high energy by-pass feed for high producing dairy cows. Feeding it can decrease feed intake, yet increase the milk output without compromising its fat content. HPFAD is a similar high energy feed to CSPFAD.

From Other By-Products

OPF suplemented with PPF and dried POME can also be animal feed. The use of these by-products will result in substantial savings to the livestock Industry as these materials are abundantly available.
CHAPTER 8:
Sustainability of The Malaysian Oil Palm Industry
One of the important challenges to the Malaysian oil palm industry is its sustainability. Contrary to allegations that Malaysian oil palm cultivation contributes to deforestation and declining biodiversity, the industry is very much regulated and committed to the three components of sustainability - social, environmental and economic development.

Social Development

Oil palm plays a big role in poverty eradication in the country by providing employment to an estimated half million people. The introduction of land development schemes under the Federal Land Development Authority (FELDA) has provided thousands of rural poor land to plant crops, such as oil palm, to earn a living.

Well-Being of Native Communities

Malaysia subscribes not only to the protection of its forests and biodiversity, but also to the well-being of its native communities depending on the forest for their livelihood. There is clear recognition of indigenous and native customary rights (NCR) over land, and the constitution protects the rights critical to maintaining the special relationship between the native communities and their lands. Any development of native land has to consider the interest of the people who will be encouraged to participate in the project.

Besides, there are government agencies and NGOs to protect native interests. For example, Jabatan Kemajuan Orang Asli (Department of Orang Asli Development) (JAKOA), a government agency under the Ministry of Rural and Regional Development, oversees the well-being of the orang asli (aborigines, the natives in West Malaysia). There are also legislations to protect the interests of the natives, such as the Aboriginal Peoples Act (1954), which provides for the establishment of orang asli reserves.

Conservation and Management of the Environment

There are several laws in Malaysia to protect the environment, and Good Agricultural Practices (GAPs) are generally practiced by its oil palm industry for sustainable production. Further, MPOB has its Codes of Practices (CoPs) for the palm oil supply chain to ensure good agricultural practices and product quality.

MPOB Codes of Practices (CoPs)

CoPs was launched in 2007 to harmonize the industry practices in the country for quality, food safety and sustainability. There are actually six codes – for the nursery, smallholder and estate, mill, palm kernel crusher, refinery and bulking installation. MPOB awards a certificate for compliance, after an audit of the applicant’s practices.
**Manual for Sustainable Production of Palm Oil**

MPOB has published a ‘Manual for Sustainable Production of Palm Oil’ in 2009, based on four principles for sustainability - transparency, systematic approach, living document and broad application. The manual is to guide stakeholders and the industry to open and inclusive discussion on the approaches that can be taken for sustainability in the production of palm oil.

**Roundtable on Sustainable Palm Oil (RSPO)**

RSPO is a multi-stakeholder platform, established in 2004, to promote the production, procurement and use of sustainable palm oil. A set of eight principles for sustainable palm oil production was adopted in November 2005. In 2013, it added another four with changes to the existing ones. The criteria now include a requirement to assess and report GHG emission from the existing plantation, mill and new plantings.

**Malaysian Sustainable Palm Oil (MSPO)**

Malaysia also recognises the need to have its own standard for sustainable palm oil production. Thus, MSPO was drawn up in consultation with the stakeholders and relevant agencies of the Malaysian oil palm industry. There are seven principles - management commitment and responsibilities; transparency; compliance to legal requirements; social responsibility, health, safety and employment conditions; best practices; environment, natural resources, biodiversity and ecosystem services; and new plantings. The requirements apply to independent smallholders, plantations and organised smallholders, and palm oil mills. They will be expanded to other sectors in the supply chain, such as palm kernel crusher, refinery and biofuel/biomass plant soon. A certificate will be awarded for compliance, after an audit by a third party. The audit report will be available on request (except those parts that impinge on commercial confidentiality or which disclosure can result in negative environmental and social outcomes).
In the last 10 years, the Malaysian oil palm industry has been accused of rainforest destruction and causing a decline in the orang utan population. The Malaysian government and oil palm industry have carried out numerous conservation initiatives to sustain the endemic wildlife in the Kinabatangan area of Sabah. Sabah has been the focus of these activities as it is where the largest population of orang utan in Malaysia exists. Also, the forests contain a remarkable diversity and abundance of wildlife, and some iconic and endemic species, such as the proboscis monkey, Bornean gibbon, Bornean elephant and clouded leopard.

The oil palm industry on its own, for example, Sime Darby, has also been active in its own conservation efforts, particularly in and around its estates. Some of the projects (completed and on-going) were/are the Tabin Wildlife Reserve Programme, Borneo Rhinoceros Sanctuary and Restoration and Protection of Orang Utan Habitat in Northern Ulu Segama.

In addition, meetings have been organised to create awareness – 2009 Orang Utan Conservation Colloquium and 2012 Sabah Wildlife Conservation Colloquium (SWCC) - by the Malaysian Palm Oil Council (MPOC) in collaboration with Sabah Wildlife Department and HUTAN.

Economic Development of the Nation

Malaysia intends to become a high income nation by 2020, focusing on 12 National Key Economic Areas (NKEAs) of which the palm oil sector is one. The oil palm industry is not only one of the major earning sectors for the country but also one providing trickle-down effects to the economy. It has, for example, already spawned the oleochemicals industry, now one of the largest in the world. And oil palm wood is a nascent industry on the verge of flight.

Conclusion

Malaysia is proud of its oil palm industry, not only for its economic success but also for its increasing sustainability brought on by more and more voluntary adoption of best practices. Nevertheless, it recognizes that life is a journey, not a destination, and that however far it has travelled, there is always further to go. Thus, it values criticism for its wrongs and suggestions for its future direction(s).
RECOMMENDED READINGS


ZAWAWI IBRAHIM, ASTIMAR ABDUL AZIZ, RIDZUAN RAMLI, ANIS MOKHTAR, SIJOON LEE, ROSMAZI OMAR and AHMAD SIRAJUDDIN TABARI (2014). Production of Medium Density Fibreboard (MDF) from Empty Fruit Bunch (EFB) with Wood Fibres Mix. *MPOB TOT No.: 554*.


ADDRESSES

MPOB HEADQUARTERS AND REGIONAL OFFICES

HEAD OFFICE
Malaysian Palm Oil Board
6, Persiaran Institusi, Bandar Baru Bangi
43000 Kajang, Selangor
Malaysia

Tel. No. : +60 (0)3 8769 4400
Fax : +60 (0)3 8925 9446
Website : www.mpob.gov.my

Malaysian Palm Oil Board (MPOB)
Technical Advisory Services
West & Central Asia Regional Office

Regional Manager : Mr. Mohd Fairus Mohd Hidzir
No.G-30/6, Sea Breeze Villas
Block 8, Kehkashan, Clifton
G.P.O. Box No. 1352
Karachi-74200
Pakistan

Tel : +92 21 3583 1823 / 3583 2252
Fax : +92 21 5831 779
Email : mpobkhi@yahoo.com

Malaysian Palm Oil Board (MPOB)
Technical Advisory Services
Americas Regional Office

Regional Manager : Mr. Johari Minal
3516 International Court, N.W.
Washington, D.C. 20008,
U.S.A.

Tel : +1 (202) 572 9719 / 9768
Fax : +1 (202) 572 9783
Email : mpobtas@gmail.com
Malaysian Palm Oil Board (MPOB)
Technical Advisory Services
Americas Regional Office

Regional Manager : Mr. Johari Minal

3516 International Court, N.W.
Washington, D.C. 20008,
U.S.A.

Tel : +1 (202) 572 9719 / 9768
Fax : +1 (202) 572 9783
Email : mpobtas@gmail.com

Malaysian Palm Oil Board (MPOB)
Technical Advisory Services
Europe Regional Office

Regional Manager : Dr. Kalanithi Nesaretnam c/o Embassy of Malaysia

Avenue de Tervueren 414A
1150 Brussels
Belgium

Tel : +32 2 7628 997
Fax : +32 2 7628 998
Email : mpoobbrussels@gmail.com

Palm Oil Research & Technical Service Institute of Malaysia Palm Oil Board (PORTSIM)
Technical Advisory Services

Regional Manager : Dr. Ooi Cheng Keat

Level 2, No 18, Lane 88
Yuanshan Road
Xinzhuang Industrial Park
Minhang, Shanghai 201108
P.R. China

Tel : +8621 6442 3303
Fax : +8621 6442 3866
Email : portsim@mpob.com.cn
Malaysian Palm Oil Board (MPOB)
Technical Advisory Services

India Branch Office
Regional Manager : Dr. Nagendran Bala Sundram

Unit No. 12, Ground Floor,
Rupa Solitaire Building, Building No. A-1, Sector 1,
Millenium Business Park,
Mahape, Navi Mumbai,
Maharashtra, India.

Email : nagen@mpob.gov.my

Other Government Offices and Related Organisations

Ministry of Plantation Industries and Commodities (MPIC)
15, Aras 6-13
Persiaran Perdana, Precint 2
62654 Putrajaya
MALAYSIA

Tel : +603-8000 8000
Fax : +603-8880 3482
Website: www.mpic.gov.my

Ministry of International Trade and Industry (MITI)
Menara MITI, No. 7
Jalan Sultan Haji Ahmad Shah
50480 Kuala Lumpur
MALAYSIA

Tel : +603-8000 8000
Fax : +603-6202 3446
Website : www.miti.gov.my

Malaysian Palm Oil Association (MPOA)
12th Floor, Bangunan Getah Asli (Menara)
148 Jalan Ampang
50450 Kuala Lumpur
MALAYSIA

Tel: +603-2710 5680
Fax: +603-2710 5679
Website: hwww.mpoa.org.my
Malaysian Palm Oil Council (MPOC)
2nd. Floor, Wisma Sawit,
Lot 6, SS6, Jalan Perbandaran,
47301 Kelana Jaya,
Selangor Darul Ehsan,
MALAYSIA

Tel: +603 - 7806 4097
Fax: +603 - 7806 2272
Website: www.mpoc.org.my

Palm Oil Millers Association (POMA)
No. 27 Jalan Sooah Yong
Taman Canning
31400 Ipoh
Perak
MALAYSIA

Tel: +605-548 2279
Fax: +605-545 0380

Palm Oil Refiners Association of Malaysia (PORAM)
801C/802A, Bolck B, Executive Suites
Kelana Business Centre
97, Jln SS7/2
47301 Kelana Jaya
Selangor
MALAYSIA

Tel: +603-7492 0006
Fax: +603-7492 0128
Website: www.poram.org.my

Malaysian Oleochemical Manufacturers Group (MOMG)
Malaysian Biodiesel Association (MBA)
c/o Chemical Industries Council of Malaysia (CICM)
Federation of Malaysian Manufacturers (FMM)

Wisma FMM, No. 3, Persiaran Dagang
PJU 9, Bandar Sri Damansara
52200 Kuala Lumpur
MALAYSIA

Tel: +603-6286 7200
Fax: +603-6277 6714
Website: www.fmm.org.my