FUTURE PROSPECTS FOR PALM OIL PROCESSING

Dr. V. Gibon,
Desmet Ballestra Group,
Zaventem, Belgium

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Composition of Crude Palm Oil

- Produced at oil mill by cooking, pressing and clarification.

- Quality of the crude oil affects:
  - Efficiency and yield of the refining.
  - Quality of the fully processed oil.

- Beside triacylglycerols, multitude of chemical entities, some with actual or potential value:
  - Free fatty acids (FFA) and partial acylglycerols.
  - Oxidation products and metal traces.
  - Phosphatides and glycolipids.
  - Tocopherols and tocotrienols.
  - Carotenoids.
  - Sterols, methyl sterols, triterpenes/isoprenoid alcohols, hydrocarbons.
Refining Options

Crude Oil

Chemical Refining

Degumming

Neutralisation

Bleaching

Deodorisation

Physical Refining

Degumming

SOAPS

GUMS

FFA

SPLITTING

Bleaching

Steam refining-Deodorisation

Refined Oil
Physical refining:

• Higher oil yield.
• Use of less chemicals and water; less effluent.
• Reduction of environmental impact.

Final choice depends on:

• Quality and acidity of the crude oil
  (wide range of undesirable products more easily removed by chemical refining)
• Ability to get rid of soapstocks.
• Local environment legislation.

Crude palm oil with high acidity, low phosphatides, high carotene:

• Physical refining is preferred (operating costs and refining losses).
• The process can be optimized (retention of minor components (tocos)).

Chemical refining still used at a limited capacity.
## Quality Specifications

<table>
<thead>
<tr>
<th></th>
<th>Special quality (SQ) grade</th>
<th>Std quality I</th>
<th>Std quality II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FFA (% max)</strong></td>
<td>2.5</td>
<td>3.5</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>M and I (% max)</strong></td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>PV (meq O₂/kg max)</strong></td>
<td>2.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>AnV (max)</strong></td>
<td>4.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>DOBI (min)</strong></td>
<td>2.8</td>
<td>2.5</td>
<td>2.2</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Special grade</th>
<th>Lotox</th>
<th>Std</th>
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<tbody>
<tr>
<td><strong>FFA (% max)</strong></td>
<td>2.5</td>
<td>2.5</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>Carotene (ppm max)</strong></td>
<td>-</td>
<td>600-700</td>
<td>-</td>
</tr>
<tr>
<td><strong>Fe (ppm max)</strong></td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Cu (ppm max)</strong></td>
<td>0.02</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>
• FFA < 3% guarantee fresh and unbruised fruits, good storage and transportation.
• Freshly expelled crude palm oil allows low hydrolysis and oxidation.
• High FFA is usually combined with high Fe and Cu levels; Fe and Cu have high pro-oxidant potential.
• Low grade crude palm oils suffers auto-oxidation of carotene.

→ **DOBI** (Deterioration Of Bleachability Index) [ISO 7932:2005]:

Good test to assess crude palm oil quality.

\[
\text{DOBI} = \frac{\text{UV absorbance (446nm)}}{\text{UV absorbance at 269 nm}} \times \frac{\text{carotene}}{\text{oxidation products}}
\]

- **DOBI** above 2.5 (easily refined) [above 3: very satisfactory quality].
- **DOBI** between 2.0 and 2.5 (unpredictable).
- **DOBI** below 2.0 (difficult to refine).
**DOBI of Crude Palm Oil and Color of the Refined Oil**

<table>
<thead>
<tr>
<th>Crude Palm Oil</th>
<th>Bad grade</th>
<th>Poor grade</th>
<th>Poor grade</th>
<th>Poor grade</th>
<th>Fair grade</th>
<th>Good grade</th>
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<tbody>
<tr>
<td>FFA (%)</td>
<td>7.21</td>
<td>4.32</td>
<td>3.54</td>
<td>4.91</td>
<td>2.79</td>
<td>1.90</td>
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<tr>
<td>DOBI</td>
<td>1.34</td>
<td>1.76</td>
<td>2.02</td>
<td>2.23</td>
<td>2.67</td>
<td>3.13</td>
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<tr>
<td>PV (meq O₂/kg)</td>
<td>2.33</td>
<td>3.79</td>
<td>3.15</td>
<td>3.54</td>
<td>0.36</td>
<td>1.03</td>
</tr>
</tbody>
</table>

**RBD Palm Oil**

| Lovibond (5°1/4) | 3.1R/33Y | 3.0R/35Y | 2.2R/20Y | 2.0R/20Y | 1.3R/15Y | 1.4R/15Y |

**Heat-bleached palm oil with color below 2R can only be produced when crude palm oil has a DOBI above 2.5.**
Deodorisation: crucial refining stage, important effect on final oil quality

**Targets:**
- Bland taste and smell
- Low FFA and no hydrolysis
- High oxidative stability
- Light and stable color
- (Removal of contaminants)

**Unwanted side effects:**
- Formation of trans FA
- Polymerisation
- Acyl-migration *(intra-esterification)*
- Degradation of natural vitamins and anti-oxidants
**Improved Deodorisation**

1) Low “trans” content
2) Retention of minor components

**Principle of Dual Temperature Deodorizer**

1) Moderate temperature - long time (stage 1)
   Mild deodorisation and moderate stripping
   - deodorisation and deacidification -

2) High temperature - short time (stage 2)
   Final stripping and heat bleaching
   - controlled stripping of valuable minor components -
**Improved Deodorisation**  
Recovery of valuable by-products

**Double Condensing System**
- Increases acidity of the fatty acid distillate
- Recovers valuable by-products

<table>
<thead>
<tr>
<th>PFAD (fatty acid distillate)</th>
<th>Chemical Refining</th>
<th>Physical Refining</th>
<th>DCS</th>
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<tbody>
<tr>
<td>FFA (%)</td>
<td>33-50</td>
<td>80-85</td>
<td>88.0</td>
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<tr>
<td>Neutral oil (%)</td>
<td>25-33</td>
<td>5-10</td>
<td>2.0</td>
</tr>
<tr>
<td>MAG (%)</td>
<td></td>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>DAG (%)</td>
<td></td>
<td></td>
<td>8.0</td>
</tr>
<tr>
<td>TAG (%)</td>
<td></td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>Unsap. (%) (tocos, sterols ...)</td>
<td>25-33</td>
<td>2-8</td>
<td>2.0</td>
</tr>
</tbody>
</table>
**Improved Deodorisation**

1) Low operating pressure
2) Reduction of emission and effluents

**Dry (Ice) Condensing System**

- From FA scrubber
- Freeze condenser
- To de-aeration
- LP steam
- Melt vessel
- Condensate
- Condenser
- Cooling water
- Compressor
- Separator
- Condensate

Condensation of steam (into ice) on surface condensers

Low pressure can be reached (< 2 mbar)

Strongly reduced odor emission

10x less waste water

Nearly no motive steam ; higher electricity consumption
**Specially Refined Palm Oil**

Golden Palm Oil (physically refined):

Dual temperature/low pressure (ice condensing vacuum)

<table>
<thead>
<tr>
<th></th>
<th>RBD Palm Oil Ref.</th>
<th>Golden Palm Oil A</th>
<th>Golden Palm Oil B</th>
<th>Golden Palm Oil C</th>
<th>Golden Palm Oil D</th>
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<tbody>
<tr>
<td>FFA (%)</td>
<td>0.07</td>
<td>0.20</td>
<td>0.07</td>
<td>0.08</td>
<td>0.07</td>
</tr>
<tr>
<td>Lovibond 5”1/4 (R/Y)</td>
<td>2.5/25</td>
<td>11.6/70</td>
<td>6.2/50</td>
<td>4.8/50</td>
<td>4.1/42</td>
</tr>
<tr>
<td>Tocos (ppm)</td>
<td>545</td>
<td>709</td>
<td>671</td>
<td>630</td>
<td>699</td>
</tr>
<tr>
<td>OSI (h at 97.8°C)</td>
<td>70.5</td>
<td>61.5</td>
<td>63.0</td>
<td>50.6</td>
<td>53.4</td>
</tr>
</tbody>
</table>
High Vitaminic Palm Oil (chemically refined):

<table>
<thead>
<tr>
<th></th>
<th>Crude</th>
<th>Degum. and Neutr.</th>
<th>Degum., Neutr. and Deod.</th>
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<tbody>
<tr>
<td>FFA (%)</td>
<td>2.56</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>Phosphorus (ppm)</td>
<td>16</td>
<td>3</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>DOBI</td>
<td>3.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carotene (ppm)</td>
<td>580</td>
<td>579</td>
<td>1.0</td>
</tr>
<tr>
<td>Tocos (ppm)</td>
<td>733</td>
<td>679</td>
<td></td>
</tr>
</tbody>
</table>

Thermal bleaching at lower temperature (+ Dry fractionation)

Red Cooking Palm Oils: Carotino Cooking Oil, Nutrolein Golden Palm Oil, Sioma Oil, …

| Carotene (ppm) | 600-800 |
| Tocos (ppm)    | 700-900 |

Total tocopherol (ppm):
- α- tocopherol: 227
- β- tocopherol: 202
- γ- tocopherol: -
- δ- tocopherol: 25

Total tocotrienol (ppm):
- α- tocotrienol: 656
- β- tocotrienol: 188
- γ- tocotrienol: 407
- δ- tocotrienol: 61
**Specially Refined Palm Oil**

**White Soaps from Physically Refined Palm Oil**

| High Quality Crude Palm Oil (DOBI > 3) + Optimized Refining Conditions |
|---|---|---|
| Target: Saponification color < 3R (Lovibond 5"1/4) | RBD Oil Color (R Lovibond 5"1/4) | Saponification Soap Color (R Lovibond 5"1/4) |
| Conditions 1 | 0.9 | 3.6 |
| Conditions 2 | 0.7 | 2.8 |
| Conditions 3 | 0.6 | 2.5 |

**Feedstock for Fractionated Products**

Specialty Fats

TAG composition not be affected (optimal SUS/SSU: 8)

Optimized refining conditions

S: saturated; U: unsaturated FA

![Graph showing SUS/SSU vs. Deo temperature over time](image)
Dry Fractionation Of Palm Oil

Where is Fractionation used in Palm Oil processing?

- Food
  - RB(D) PO (Commodity Fats, Special Products)
  - Fractionation
    - Oleins
    - Stearins

- Nonfood
  - FFA
  - Fractionation
    - Oleic Acid
    - Stearic Acid

- Biofuel
  - FAME
  - Fractionation
    - Oleic FAME
    - Stearic FAME
**Dry Fractionation Of Palm Oil**

**Crystallization developments**

- two approaches:  **“slow”** crystallisation / long cycle (Tirtiaux)
  **“fast”** crystallisation / short cycle (De Smet)

- semicontinuous (batch) to continuous

- high shear, low shear (agitation) vs static (block crystallisation)

  eg. PO

  eg. PO/PKO
Membrane press filter developments

Any development in press filtration?

Bigger size → 25m³

Bigger plates → 2x2m

Higher pressure → 50 bar
Dry Fractionation Of Palm Oil

Dynamic Concentric Crystallisers

Concentric Cooled Walls
Dry Fractionation Of Palm Oil

Dynamic Tirtiaux Crystallisers

Cooling Fins
Dry Fractionation Of Palm Oil

Low Shear Crystalliser
(special cooling surface configuration)

Near static crystallisation
Static Crystalliser
(for controlled block crystallisation)

Filter press

2005/12/09
Heterogeneous TAG distribution → separation of compositionally distinct fractions

**100% Palm Oil**
- IV 52

**15% Palm Stearin**
- IV 36

**85% Palm Olein**
- IV 56

**45% Soft PMF**
- IV 46

**30% Mid Olein**
- IV 53

**20% Mid Olein**
- IV 60

**40% Super Olein**
- IV >64

**40% Super Olein**
- IV >64

**20% Top Olein**
- IV >67

**Very cold stable salad oil**

**Margarine**

**Frying Oil**

**Salad Oil**

**Commodity Fats**

**Specialty Fats**
Signicative enrichment of POP in the Hard PMF

<table>
<thead>
<tr>
<th>%</th>
<th>PO IV 52</th>
<th>POI IV 56</th>
<th>SPMF IV 46</th>
<th>SPMF IV 45</th>
<th>HPMF IV &lt; 35</th>
<th>HPMF IV &lt; 35</th>
<th>CB</th>
</tr>
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<tbody>
<tr>
<td>DAG</td>
<td>5.0</td>
<td>5.2</td>
<td>3.8</td>
<td>3.6</td>
<td>2.0</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>PPP</td>
<td>5.2</td>
<td>0.4</td>
<td>0.2</td>
<td>0.8</td>
<td>0.9</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>StOSt</td>
<td>0.3</td>
<td>0.2</td>
<td>1.1</td>
<td>0.9</td>
<td>1.3</td>
<td>1.1</td>
<td>26</td>
</tr>
<tr>
<td>POSt</td>
<td>5.0</td>
<td>5.0</td>
<td>9.3</td>
<td>8.5</td>
<td>11.0</td>
<td>12.1</td>
<td>37</td>
</tr>
<tr>
<td>POP</td>
<td>29.3</td>
<td>29.9</td>
<td>48.7</td>
<td>47.8</td>
<td>66.0</td>
<td>64.0</td>
<td>18</td>
</tr>
</tbody>
</table>
Solid fat content profile similar to Cocoa Butter

Special products: CBE
High POP Fractions

- HPMF IV < 35
- HPMF "Solvent grade"
- CB

Solid fat content (SFC) (%) tempered vs. temperature (°C)
**Special products:**
Red Palm Fractions

### Golden Palm Oil
IV 51-53

### Olein
IV 57-59

### Salad Oils

### Superolein
IV 64-66

### Red Palm Oil
51.9, 21.6, 382 [IV, Cloud Point (°C), Carotene (ppm)]

### Red Olein
56.7, 8.1, 409

### Red Superolein
63.2, 3.3, 670

### Red Topolein
71.3, -2.4, 854

### Cold resistant and high vitatiminic liquid fractions

### Red solid fractions

- **Stearin**
  - 281 ppm Carotene

- **Soft PMF**
  - 235 ppm Carotene

- **Hard PMF**
  - 80 ppm Carotene
Palm Olein IV 56-57
Same TAG distribution

Softness increased when DAGs increased (poor quality crude oil)
Influence of DAGs on Final Product Quality

Palm Olein IV 56-57
Same TAG distribution
Cloud point increased when DAGs increased (poor quality crude oil)
Enzymatic Interesterification: 
“low trans” Commodity Fats

EIE = RANDOM re-distribution of FA on the glycerol:
→ improved oxidative stability (iso chemical interesterification)

![Diagram showing enzymatic interesterification reactions and SFC (Saponification Number Content) graph](image)

- ACA
- BBB
- TL IM (Novozymes) nonspecific
- AAA BBB CCC
- ABA BBB BAC
- AAB BBC ACA
- BBC BBA BAB BCB
- CCA CCB CAC CBC
• **Continuous process**: less suitable in case of many stock changes.
• Used in **fixed bed** for better process economy.
• **Simple, clean and safe process** (70°C).
• **Limited cross contamination**.
• **Increased stability of the enzyme** → ‘economical’ operating costs.
• **No side reactions, no post-bleaching**.
• **Less oil losses**.
• **Better oxidative stability**.
Enzymatic Interesterification: “low trans” Commodity Fats

- Liquid Oil
- Blending
- Hard Fat (Fractionated or fully hydrogenated)
- Deodorizing
- Enzyme Process
- SFC 1
- SFC 2
- SFC 3
- Finished Margarine/Shortening Fat
- Base Stocks
- Liquid Oil
EIE = **Regio-selective** re-distribution of the FA on the glycerol:

→ sn 1,3 selective enzyme

- **Confectionery fats** (high SUS: CBE; anti-blooming: BOB)
- **Infant formula** (high UPU, P in sn 2): readily absorbed by infants
- **Easily absorbable and low calory fats** (MedUMed)
Strategy: ‘structuring’ POP lipid into StOSt/POSt/POP lipid

POP matrix + Stearic acid or Stearic methyl ester

sn 1,3 specific EIE

StOSt/POSt/POP matrix + FFA/FAME

Stripping

StOSt/POSt/POP matrix

Dry Fractionation

CBE
EIE and Dry Fractionation for CBE Production

<table>
<thead>
<tr>
<th>%</th>
<th>SPMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSS</td>
<td>1.0</td>
</tr>
<tr>
<td>StOSt</td>
<td>1.6</td>
</tr>
<tr>
<td>POSt</td>
<td>9.0</td>
</tr>
<tr>
<td>POP</td>
<td>48.0</td>
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</table>

Specific EIE

+ “S” FFA/FAME

<table>
<thead>
<tr>
<th>%</th>
<th>EIE</th>
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<tbody>
<tr>
<td>SSS</td>
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<tr>
<td>StOSt</td>
<td>15.0</td>
</tr>
<tr>
<td>POSt</td>
<td>33.0</td>
</tr>
<tr>
<td>POP</td>
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</table>

Stripping /Dry Fractionation

<table>
<thead>
<tr>
<th>%</th>
<th>FRAC₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSS</td>
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<tr>
<td>StOSt</td>
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<tr>
<td>POSt</td>
<td>36.0</td>
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CBE

<table>
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<tr>
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<th>FRAC₂</th>
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<tr>
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<tr>
<td>POSt</td>
<td>43.0</td>
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<td>POP</td>
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</table>

<table>
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<tr>
<th>%</th>
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<tbody>
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<td>POSt</td>
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<td>POP</td>
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<table>
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<td>POSt</td>
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<td>POP</td>
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<table>
<thead>
<tr>
<th>%</th>
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<tr>
<td>POSt</td>
<td>34.0</td>
</tr>
<tr>
<td>POP</td>
<td>13.0</td>
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</tbody>
</table>
Enzymatic Interesterification Plant

Lab reactor

Pilot unit

Industrial plant
Take home messages:

• Rich in **minor components** (tocopherols and tocotrienols (vitamin E) and carotenoids (alpha and beta carotene)) impart unique nutritional properties that need to be preserved

• Processing duality: target unwanted side effects

  Improved refining technologies:

  Dual Temperature, Double Condensing, Ice Condensing

• Crude oil quality

  Low Acidity, High DOBI, Low partial acylglycerols

• Easily « fractionable » → **commodity fats + special products (CBE)**

  New fractionation developments to improve quality and yield

• Feedstock for **enzymatic interesterification**

  Commodity fats (margarines and shortenings

  Special products (CBE, infant formula, …)
Science behind Technology

Thank you very much for your attention