Introduction to Palm Oil-2

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Palm Oil Processing Flow Chart
Palm Oil Processing
Flow Chart

Harvesting

Palm Oil Processing
Flow Chart
Oil palms generally begin to produce fruits 30 months after being planted in the fields with commercial harvest commencing six months later.

However, the yield of an oil palm is relatively low at this stage.

As the oil palm continues to mature, its yield increases and it reaches peak production in years seven to 18.

Yield starts to gradually decrease after 18 years.

The typical commercial lifespan of an oil palm is approximately 25 years.

- Fully mature oil palms produce 18 to 30 metric tonnes of fresh fruit bunches (FFB) per hectare.
- The yield depends on a variety of factors, including age, seed quality, soil and climatic conditions, quality of plantation management and the timely harvesting and processing of FFB.
- The ripeness of FFB harvested is critical in maximising the quality and quantity of palm oil extracted.
- Harvested fruits must be processed within 24 hours to minimise the build-up of fatty acids.
Transportation of FFB

Palm Oil Processing Flow Chart

Fresh Fruit Bunch (FFB) Received At Mill

Palm Oil Processing Flow Chart
FFB Loaded Into Cages Ready for Sterilization

Palm Oil Processing Flow Chart
Palm Oil Processing

Flow Chart

Sterilizer

Loading to Sterilizer
Palm Oil Processing Flow Chart

- Milling of FFB takes place within 24 hours from the harvesting of FFB.
- FFB are first transferred to the palm oil mills for sterilisation by applying high-pressure steam, whereupon the palm fruits are enzyme-deactivated and separated from the palm bunches.
- After steaming, the palm fruitlets are crushed in a pressing machine to obtain crude palm oil (CPO) and palm kernel.
- Waste and water is then cleared and separated from the CPO by means of a centrifuge.

Palm Oil Processing Flow Chart

- The cleared crude palm oil emerging from the centrifuge is then sent for refining while the palm kernel nut is sent for crushing.
- The empty fruit bunches and liquid waste arising from the process are recycled as fertiliser in the plantations.
**Sterilization**

- Placing sterilizer cages in horizontal vessels at steam pressure of 3 kg/cm² (143°C); 60 minutes
  - Enzyme inactivation \(\rightarrow\) prevention of FFA increase
  - Facilitation of mechanical stripping
  - Preparation of pericarp for sub-sequential processing
  - Preconditioning of the nuts to minimize kernel breakage
Palm Oil Processing

Unit Operations

Stripping
- Separation of sterilized fruits from the bunch stalks
- Drum type:
  - Vigorous shaking
  - Beating

Digestion
- Reheating the sterilized fruits (mixing the fruits at 95-100°C, 20 minutes.
  - To loosen the pericarp from the nuts
  - To break the oil cell before passing to oil extraction unit
Palm Oil Processing

Unit Operations

Oil Extraction

- Continuous screw pressing to produce:
  - Mixture of oil (~66%), water (~24%) and non-oily solid (~10%).
  - Press cake, containing fibers and nuts

Clarification

- Dilution with water – to facilitate settling
  - Screen – to remove fibrous material
  - Pump to settling tank – to obtain oil and sludge

  - “Top” oil is skinned off → centrifuge → vacuum dryer → oil storage
  - Sludge (~10% oil) → reclaimed and fed back to main settling tank
Clarification

Palm Oil Processing
Unit Operations

Oil Storage

- Internally coated with epoxy material to prevent iron pickup
- Oil : water content 0.1 -0.12%; impurities < 0.02%.
- Temperature controlled : Storage 32-40°C,
  (loading/unloading : 50-55°C (heating rate 5°C per 24 hr)
Palm Oil Processing

Flow Chart

CPO

- Color: Dark Red
- Rich in Micronutrient: (Carotenoids; Tocoferol; Tocotrienol; Fitosterol)
- Need to be refined

Refining Process

Commonly consists of desirable triglycerides, unsaponifiable matter together with small amount of impurities.

- Impurities contribute undesirable effects to the oil, for instance color, flavor, odor, instability and foaming.
- Should be removed by a purification step in order to produce good quality of refined oil with minimal possible oil loss or damage to the oil and desirable materials such as tocopherols and carotenes.
Palm Oil Processing Flow Chart

CPO

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Crude Palm Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triglycerides, %</td>
<td>95</td>
</tr>
<tr>
<td>Free Fatty Acids, FFA, %</td>
<td>2 - 5</td>
</tr>
<tr>
<td>Red Colour (5 ‰ Lovibond Cell)</td>
<td>Orange red</td>
</tr>
<tr>
<td>Moisture &amp; Impurities, %</td>
<td>0.15 – 3.0</td>
</tr>
<tr>
<td>Peroxide Value, PV (meq/kg)</td>
<td>1 - 5.0</td>
</tr>
<tr>
<td>Anisidine Value, AV</td>
<td>2 – 6</td>
</tr>
<tr>
<td>β-carotene content, ppm</td>
<td>500-700</td>
</tr>
<tr>
<td>Phosphorus, P, ppm</td>
<td>10-20</td>
</tr>
<tr>
<td>Iron (Fe), ppm</td>
<td>4-10</td>
</tr>
<tr>
<td>Tocopherols, ppm</td>
<td>600-1000</td>
</tr>
<tr>
<td>Diglycerides, %</td>
<td>2-6</td>
</tr>
</tbody>
</table>

Oil
Triglyceride, Diglyceride, Monoglyceride; Phospholipids, Glycolipid and Lipoprotein; Free fatty acids

Oxidized Products
Peroxides, Aldehydes, Ketones, Furfurals (from sugars)

Non-oil (but oil soluble)
Carotene, Tocopherols, Squalene, Sterols

Impurities
Metal particles, Metal ions, Metal complexes

Water Soluble
Water (moisture), Glycerol, Chlorophyll pigments, Phenols, Sugars (soluble carbohydrates)
Palm Oil Processing Flow Chart
– further processing (refining process)

Physical Refining

Chemical Refining

CPO
- Degumming of CPO

- Crude oils contain complex organo-phosphorus compounds referred to as phospholipids (phosphatides) or more usually, as gums.
- Phospholipids should be removed because of their strong emulsifying action and if they are not removed, the oil will went through undue darkening during deodorization at high temperature.
- The phospholipids (phosphatides) are removed during processing by a variety of treatments collectively referred to as degumming.
- The treatment usually involves hydration with water, orthophosphoric acid, and polybasic organic acids either singly or in combination, followed by centrifuging the precipitated material or by its adsorption on bleaching earth or filter.

\[
\begin{align*}
X &= \text{choline (phosphatidyl choline or PC)} \\
X &= \text{ethanolamine (phosphatidylethanolamine or PE)} \\
X &= \text{inositol (phosphatidylinositol or PI)} \\
X &= \text{hydrogen (phosphatidyl acid or PA)}
\end{align*}
\]
Palm Oil Refining Processing
Unit Operations

-Degumming of CPO

<table>
<thead>
<tr>
<th>Phospholipid</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphatidylcholine (PC)</td>
<td>36</td>
</tr>
<tr>
<td>Phosphatidylethanolamine (PE)</td>
<td>24</td>
</tr>
<tr>
<td>Phosphatidylinositol (PI)</td>
<td>22</td>
</tr>
<tr>
<td>Phosphatidylglycerol</td>
<td>9</td>
</tr>
<tr>
<td>Disphosphatidylglycerol</td>
<td>4</td>
</tr>
<tr>
<td>Phosphatic Acid (PA)</td>
<td>3</td>
</tr>
<tr>
<td>Lysophosphatidylethanolamine</td>
<td>2</td>
</tr>
<tr>
<td>Phosphatidylserine</td>
<td>trace</td>
</tr>
<tr>
<td>Lysophosphatidylcholine</td>
<td>trace</td>
</tr>
</tbody>
</table>
Palm Oil Refining Processing

Unit Operations

-Degumming of CPO

- Treatment that is given to remove color producing substances and to further purify the fat or oil.
- The usual method of bleaching is by adsorption of the color producing substances on an adsorbent material.
- There are a lot of adsorbent materials being used in vegetable oil industry for examples; acid activated bleaching earth, natural bleaching earth, activated carbon and synthetic silicates.
- Acid activated bleaching earth (fuller’s earth) or clay, sometimes called bentonite, is the adsorbent material that has been used most extensively.
- This substance consists primarily of hydrated aluminum silicate. Usually, bleaching earth does not remove all the color producing materials, much of which are actually removed by thermal destruction during the deodorization process.
- Activated carbon is also used as a bleaching adsorbent to a limited extent.

-Palm Oil Refining Processing

Unit Operations

-Bleaching of CPO

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• This substance consists primarily of hydrated aluminum silicate. Usually, bleaching earth does not remove all the color producing materials, much of which are actually removed by thermal destruction during the deodorization process.
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Palm Oil Refining Processing

Unit Operations

- Deodorization of CPO
  - Deodorization is a vacuum steam distillation process for the purpose of removing undesirable flavors and odors, mostly arising from oxidation, in fats and oils.
  - Using steam under reduced pressure the volatile compounds are removed from fats and oils.
  - Typical conditions approximate 250°C at 2.0 mm absolute pressure for 1-4 hr with strong steam sparging.
  - The deodorization utilizes the differences in volatility between off-flavor and off-odor substances and the triglycerides.

### Typical deodorization conditions

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Chemical Refining</th>
<th>Physical Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U.S.</td>
<td>Europe</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>250-260</td>
<td>230-240</td>
</tr>
<tr>
<td>Pressure (mbar)</td>
<td>3-4</td>
<td>2-3</td>
</tr>
<tr>
<td>Sparge steam (%)</td>
<td>0.5-2.0</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Time (min.)</td>
<td>20-40</td>
<td>40-60</td>
</tr>
<tr>
<td>Final FFA (%)</td>
<td>0.03-0.05</td>
<td>0.03-0.05</td>
</tr>
</tbody>
</table>
Palm Oil Refining Processing

Unit Operations

- Deodorizations

<table>
<thead>
<tr>
<th>Component</th>
<th>Mol. Weight</th>
<th>Relat. volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty acid</td>
<td>280</td>
<td>2.5</td>
</tr>
<tr>
<td>Squalene</td>
<td>411</td>
<td>5</td>
</tr>
<tr>
<td>Tocopherol</td>
<td>415</td>
<td>1</td>
</tr>
<tr>
<td>Sterol</td>
<td>410</td>
<td>0.6</td>
</tr>
<tr>
<td>Sterol ester</td>
<td>675</td>
<td>0.04</td>
</tr>
<tr>
<td>Oil</td>
<td>885</td>
<td>&lt;small&gt;</td>
</tr>
</tbody>
</table>

Palm Oil Refining Processing

Unit Operations

A. Physical Refining

Diagram of physical refining process.
Palm Oil Refining Processing

Unit Operations

A. Physical Refining

-Degumming and pre-bleaching of CPO
- Add concentrated (80-85%) phosphoric acid (dose at 0.05-0.2% of fed oil), 13-30 minutes
  - Precipitate nonhydratable phosphatides
- Adsorptive cleansing with bleaching clay (add as slurry 0.8 – 2%); under vacuum 20-25 mmHg; 95-110°C, 30-45 min).
  - Adsorb impurities (trace metal, moisture, insoluble, and part of the carotenoids and other pigments
  - Adsorb/reduce oxidation products
  - Adsorb phospholipids precipitated by phosphoric acids
  - Remove any excess phosphoric acids

-Palm Oil Refining Processing

Unit Operations

A. Physical Refining

-Deacidification & Deodorizations
- Oil is deaerated \( \rightarrow \) heating 240-270°C (using external HE) \( \rightarrow \) pumped into deodorizer (2-5 mmHg).
  - Remove FFA (incl volatile odoriferous, oxidation products (aldehyde and ketone).
  - Thermally compose carotenoids
  - Produced light-colored, bland RBDPO
Palm Oil Refining Processing

Unit Operations A. Physical Refining

-Deacidification & Deodorizations

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Time (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>180°C (356°F)</td>
<td>20</td>
</tr>
<tr>
<td>200°C (392°F)</td>
<td>40</td>
</tr>
<tr>
<td>240°C (464°F)</td>
<td>60</td>
</tr>
</tbody>
</table>

Graph showing residual carotene (%):
- 100 at 20 minutes
- 80 at 40 minutes
- 60 at 60 minutes
- 40 at 20 minutes
- 20 at 40 minutes

Palm Oil Refining Processing

Unit Operations A. Physical Refining

-Desirable Quality of pretreated and RBDPO

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pretreated PO (Degummed/Bleached)</th>
<th>RBDPO</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFA (as C16:0; %)</td>
<td>Same as Crude feed</td>
<td>0.10%, max</td>
</tr>
<tr>
<td>Peroxide value (mEq/kg)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Moisture and Impurities (wt, %), max</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Iron (mg/kg), max</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Copper (mg/kg), max</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Phosphorus, (mg/kg), max</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
- Alkali Refining
  - Heating CPO to 80-90°C
  - Dose concentrated (80-85%) phosphoric acid at 0.05-0.2% (of fed oil)
  - Add caustic soda solution (4N = 20Be) with calculated excess of ~20%
  - Soap removal by centrifugation
    - Lighter phase (oil with 500-1000 mg soap/kg oil; moisture) → Neutralized Palm Oil (NPO)
    - Heavier phase (soap, insoluble impurities, gum, phosphatides, excess alkali, and loss oil/emulsion).
  - Washing NPO with 10-20% hot water → centrifugation
  - Washed oil is dried under vacuum to a moisture level < 0.05%.
- **Bleaching**
  - NPO is bleached *(similar process as that of physical refining)*
  - Adsorptive cleansing with bleaching clay (add as slurry 0.8 – 2%); under vacuum 20-25 mmHg; 95-110°C, 30-45 min).
    - Adsorb impurities (trace metal, moisture, insoluble's, and part of the carotenoids and other pigments)
    - Adsorb/reduce oxidation products
    - Adsorb phospholipids precipitated by phosphoric acids
    - Remove any excess phosphoric acids

- **Deodorization**
  - NBPO is deodorized *(similar process as that of physical refining)*
  - Oil is deaerated  → heating 240-270°C (using external HE)  → pumped into deodorizer (2-5 mmHg).
  - Remove FFA (incl volatile odoriferous, oxidation products (aldehyde and ketone).
  - Thermally compose carotenoids
  - Produced light-colored, bland NBDPO
  - RF (refining factor) :
    - RF = % total Oil Loss/% FFA in the Oil
    - 1.5 – 2.0
Palm Oil Refining Processing

Unit Operations

A. Chemical Refining

-Desirable Quality of pretreated and NBDPO

<table>
<thead>
<tr>
<th>Parameter</th>
<th>N-PO</th>
<th>NB-PO</th>
<th>NBD-PO</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFA (as C16:0; %)</td>
<td>0.15%, max</td>
<td>0.15%, max</td>
<td>0.10%, max</td>
</tr>
<tr>
<td>Peroxide value (mEq/kg)</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Moisture and Impurities (wt, %), max</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Iron (mg/kg), max</td>
<td>-</td>
<td>0.15</td>
<td>0.12</td>
</tr>
<tr>
<td>Copper (mg/kg), max</td>
<td>-</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Phosphorus, (mg/kg), max</td>
<td>-</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Soap Content (mg/kg)</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Palm Oil Processing

Flow Chart

– further processing (refining process)
Palm Oil Processing
Flow Chart
– further processing (refining process) & fractionation

S-Solid fraction
L-Liquid fraction
Palm Oil Processing
Fractionation

1. CPO
2. CP Olein
3. CP Stearin
4. RBO Olein
5. RBD Stearin
6. RBD PO

Palm Oil Processing
Fractionation

- Triacylglycerols/triglyceride (TAG) of PO consist of combination of FAs
- 3 commercial methods of fractionations
  - Dry fractionation
  - Detergent fractionation
  - Solvent fractionation
Palm Oil Processing Fractionation

- To separate olein (low-melting liquid phase) and stearin (high-melting solid phase) fraction
- Olein usually used for cooking oil
- Stearin usually for margarine and industrial frying

Palm Oil Processing Fractionation

- Dry fractionation
  - Oil is kept homogenized at 70°C
  - Cooled at specific cooling program; up to 20°C (depend on quality requirement)
  - Filtration (filter press; membrane filter)
  - About 65-75% olein + 25-35% stearin
Palm Oil Processing
Fractionation

• Dry fractionation

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• Detergent fractionation
  • Usually done on CPO
  • Hot oil is cooled up to –usually about 20°C)
  • Add and mix with aqueous detergent solution (0.5% sodium lauryl sulfate/SDS)
  • Stearin crystals are wetted with SDS → go to aqueous phase
  • Centrifugation → olein is washed with hot water → vacuum dried
  • Yield ~ 80% olein

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Palm Oil Processing
Fractionation

- Solvent fractionation
  - Most expensive, need lower temp; more safety feature
  - Hexane and acetone
  - Oil is dissolved in the solvent → cooled → filtration
  - Yield ~ 80% Olein
  - Viable in production of high value products → PMF → cocoa butter equivalent
Palm Oil Processing
Fractionation

LOW MELTING FRACTION
Yield >60%
M.Pt. <15°C
16:0 ~35%
IV > 65

PALM OIL

Acetone:oil=4:1
Crystallize at ~ 0°C

Reheat to 40°C
add more acetone
(acetone:oil=4:1)

Crystallize at 20-24°C

1st Fractionation

PALM MIDFRACTION
Yield 25-30%
M.Pt. 30-35°C
16:0 ~60%
IV > 32-36
POP = 56%
POS = 10%
SOS = 1%

2nd Fractionation

HIGH MELTING FRACTION
Yield >10%
M.Pt. 55-60°C
16:0 ~80%
IV > 10

Palm Oil Processing
Fractionation
Thank you

NEXT …
Introduction to
Palm Oil -3

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