Agenda

- Oils and fats sources
- Supply chains
- Refining or purification
  - Degumming & neutralisation
  - Bleaching
  - Deodorisation
- Process routes
- Oil modification
  - Hydrogenation
  - Fractionation
  - Interesterification
- Process routes
OILS AND FATS IN NATURE

• Not soluble in water
  - Part of cell membranes
  - Protect against external water (rain, open water)
  - Oil/fat in water emulsions (milk)

• Twice the energy content compared to other food
  - Store energy to survive periods without food
  - Supply energy at start of growth
  - Constant available energy source of the heart muscle

• Melting characteristics depends on composition
  - Consistency depending on function e.g. solid to hold organs in place and liquid in fish and plants.
  - At ambient temperature:
    • oils are liquid
    • fats are solid

• Lower density than water (floating)
• Poor heat transfer (insulation)
Oils and fats sources
Case

List the 5 most important global vegetable oils and rank them according annual production volume.
## Edible oils

<table>
<thead>
<tr>
<th></th>
<th>Oil content</th>
<th>World production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>million ton/annum</td>
</tr>
<tr>
<td><strong>Seed oils</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>18</td>
<td>48</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>40</td>
<td>27</td>
</tr>
<tr>
<td>Sunflower</td>
<td>40</td>
<td>15</td>
</tr>
<tr>
<td><strong>Fruit oils</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm</td>
<td>45</td>
<td>61</td>
</tr>
<tr>
<td>Olive</td>
<td>20</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Kernel oils</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm kernel</td>
<td>50</td>
<td>7.3</td>
</tr>
<tr>
<td>Coconut</td>
<td>34</td>
<td>3.3</td>
</tr>
<tr>
<td>Cocoa butter</td>
<td>56</td>
<td>2.6</td>
</tr>
</tbody>
</table>
## Edible oils

<table>
<thead>
<tr>
<th></th>
<th>Oil content</th>
<th>World production million ton/annum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nut oils</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundnut, arachide</td>
<td>45</td>
<td>5.6</td>
</tr>
<tr>
<td>Walnut</td>
<td>65</td>
<td>3.3 (nuts)</td>
</tr>
<tr>
<td><strong>Oil as by-product</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize germ</td>
<td>4.5</td>
<td>2</td>
</tr>
<tr>
<td>Cottonseed</td>
<td>5</td>
<td>5.1</td>
</tr>
<tr>
<td><strong>Annimal fat</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tallow (cow)</td>
<td>-</td>
<td>8.5</td>
</tr>
<tr>
<td>Lard (pig)</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Fish oil</td>
<td>-</td>
<td>1.1</td>
</tr>
<tr>
<td>Butter fat</td>
<td>3.5</td>
<td>7.1</td>
</tr>
</tbody>
</table>
Soy bean oil

Oil content: 18% - recovered by hexane extraction; 35% of crop value;
Proteins: 40%
Carbohydrates: 25%, meal for animal feed
Fibres: 3%

- Annual rotation crop with maize and cereals
- Main producing countries: USA, Brazil, Argentina, China
Oil content: 40% - recovered by pressing & hexane extraction; 75% crop value

- High fibre meal for animal feed
- Rotation crop with cereals and potatoes
- Main producing countries: Russia, South Europe, Ukraine, Argentina
Rapeseed (canola) oil

Oil content: 40% - recovered by pressing & hexane extraction; 75% crop value
Proteins: 22%
Carbohydrates: 30% meal for animal feed
Fibres: 8%

- Annual rotation crop with wheat, sugar beets, etc.
- Main producing countries: EU, China, India, Canada
Palm and Palm Kernel Oil

Palm fruit:
- Oil: 35 - 45 % recovered by pressing of the fruit
- Sludge: 45 - 55 %

Palm kernel:
- Oil: 5 % recovered by pressing of the nuts
- Meal: 5 %

Economic life: 25 years

- Main producing countries: Indonesia, Malaysia, Thailand, Nigeria
Olive Oil

Olive fruit: Oil: 19.6% recovered by pressing or centrifugation
Water: 52%
Sugar: 19%

Olive kernel: Oil: 0.4% recovered by hexane extraction of residue

- Economic life: > 100 years
- Main producing countries: Spain, Italy, Greece, Turkey.
## Yield comparison

<table>
<thead>
<tr>
<th>Oil crop</th>
<th>Crop yield t/ha (max.)</th>
<th>Oil yield t/ha</th>
<th>Second product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybeans</td>
<td>3</td>
<td>0.6</td>
<td>HQ meal</td>
</tr>
<tr>
<td>Sunflower</td>
<td>2.5</td>
<td>1.0</td>
<td>LQ meal</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>3.5</td>
<td>1.4</td>
<td>LQ meal</td>
</tr>
<tr>
<td>Oil palm</td>
<td>12</td>
<td>5</td>
<td>Kernels</td>
</tr>
<tr>
<td>Olives</td>
<td>2.5</td>
<td>0.5</td>
<td>Kernels</td>
</tr>
</tbody>
</table>
Supply chains
OILS AND FATS SUPPLY CHAIN

Extraction

by-product

Refining

Modification

Ingredient of food product
Upstream oil seed supply chain

- Oil seed farmer → Oil seed storage
- Seed control
- Oil seed storage
- Local oil mill
- Refinery
- Local use

Storage

Oil seed (IP) transport

Oil seed transport

Crude oil transport

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GD
Oil seed reception, sampling and storage
Downstream oil seed supply chain

- Storage Oil seeds (IP)
- Storage Oil seeds
- Storage crude seed oil

Oil milling

Refining

Meal

Consumer goods manufacturer
Upstream palm oil supply chain

- **Plantation**
- **Smallholders**
- **Oil mill**
- **Palm kernel mill**

**Steps in the supply chain:**
- Crude palm oil
- Palm stearin
- Palm olein
- Crude palm kernel oil

**Stages:**
- Oil mill
- Refinery
- Fractionation
- Storage

**Products:**
- Palm kerneloil
- Crude palm kernel oil
- Palm kernels
- Palm olein
- Palm stearin

**Source:** MVO - The Netherlands Oils and Fats Industry
Palm oil milling

Receiving station

- Fresh Fruit Bunches
- Steriliser
- Press
  - Bunch separation

Settling Tank

Centrifuge

Palm Oil Storage

To refinery and/or export

Sludge

Fiber/Nut Separator

Nut Cracker

Kernel Dryer

Kernel Storage

To PK mills

Sterilizer

Fibre

Shell

Bunch separation

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Overseas shipping

Overseas transport of palm products in 3 types of sea going vessels:

1. Bulk tankers. Capacity 15000 to 75000 MT, interconnected tanks. Used for large volumes of crude palm oil. Loading and discharge in several ports or port locations.

2. Parcel tankers. Capacity 15000 to 50000 MT, separated tanks of different size. Used for smaller parcels of palm fractions and palm kernel oil.

3. Coasters. Capacity 750 to 6500 MT. Used for regional transport after transshipment from ocean going vessels.
Example of a parcel tanker
Refining

Fractionation

Interesterification

Post refining

Consumer goods manufacturer

Storage crude palm oil

Storage RBD palm stearin

Storage crude palm kernel oil

Palm oil

Palm olein

Palm stearin

Palm kernel oil
Case:

List the main differences between the supply chain of soybean oil from farmer in Brazil to refinery in Europe and the supply chain of palm oil from plantation in Malaysia to refinery in Europe.
Refining or purification
Developments - 19th century

**SCIENCE**

- 1820: Fats = glycerine + fatty acids (Chevreul 1820)
- 1840: Glycerine combines with 1-3 fatty acids (1854)
- 1860: Double bond (1866)
- 1880: Iodine value (1884)
- 1900: Hydrogenation unsaturated oils (1902)

**TECHNOLOGY**

- 1844: Lye neutralisation
- 1850: Carbon adsorption
- 1866: Extraction
- 1893: Deodorization
- ca.1900: Bleaching earth
- ca. 1900: First refineries
- 1909: Hydrogenated oils in product
Current refining process - introduced in 1900

Introduction of refining due to:

- Use of coconut oil for margarine
- Decolouring of cottonseed oil
- Changing taste
- Removal of catalyst poisons before hydrogenation.
- Removal of solvents from extracted oils
<table>
<thead>
<tr>
<th>Minor component</th>
<th>Origin</th>
<th>Quality effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Fatty Acids</td>
<td>Hydrolysis</td>
<td>Off-taste, smoke during frying</td>
</tr>
<tr>
<td>Peroxides</td>
<td>Oxidation</td>
<td>Off-taste</td>
</tr>
<tr>
<td>Phosphatides</td>
<td>From cell membranes</td>
<td>Burns at high temperature</td>
</tr>
<tr>
<td>Moisture</td>
<td>From oil crop, transport &amp; storage</td>
<td>Components in free water</td>
</tr>
<tr>
<td>Dirt</td>
<td>Oil crop and harvest residues</td>
<td>Appearance</td>
</tr>
<tr>
<td>Taste &amp; odour</td>
<td>From oil crop</td>
<td>Not matching with product taste</td>
</tr>
<tr>
<td>Metals</td>
<td>Soil, milling storage &amp; transport</td>
<td>Catalyst for oxidation</td>
</tr>
</tbody>
</table>
Refining Toolbox

- Water extraction of phospholipids followed by centrifugal separation to produce lecithin
  ➔ WATER DEGUMMING

- Reaction of phospholipids with acid followed by water extraction and centrifugal separation.
  ➔ ACID DEGUMMING

- Reaction of free fatty acids with base followed by centrifugal separation.
  ➔ NEUTRALISATION

- Adsorption of minor components on clay or active carbon followed by filtration.
  ➔ BLEACHING

- Evaporation of volatile components by steam distillation.
  ➔ DEODORISATION
Degumming principles

- Seed oils are high in phospholipids (P > 200 ppm)
- P > 30 ppm requires degumming before bleaching
- Water degumming reduces P to < 200 ppm but > 100 ppm
- Acid degumming reduces P to below 30 ppm
- Water degummed oils cannot be further degummed
- Combined degumming and neutralization in one line will reduce all types of phospholipids to below 5 ppm P
Acid degumming line

Crude oil → Heat exchangers → Dynamic mixer → Static mixer → RV → Centrifuge → Degummed oil

- Steam
- Citric acid
- Water
- Drying
- Acid addition
- Water addition
- Residence time
- Gums separation
Combined degumming & neutralisation

Acid + Lye

DEGUMMING & NEUTRALISATION

BLEACHING

DEODORISATION

CRUDE OIL

Soap stock

Soapsplitting

Strong Acid

Acid oil
Acid water

REFINED OIL
Combined degumming & neutralisation

**Reaction with acid:**

Oil soluble phospholipids + acid $\rightarrow$ hydratable phospholipids

**Reaction with base:**

Oleic acid + sodium hydroxide (lye) $\rightarrow$ sodium oleate + water (soap)

Followed by separation of:

- Free Fatty Acids (soap)
- Dirt
- Phospholipids
- Water
- Metals
Recipe:
- Heat to 90 °C
- Add diluted lye
- Settle soap
- Drain soap
- Wash with water
- Dry under vacuum
Continuous neutralisation line

Crude oil → Heat exchanger → RV → RV → RV → Centrifuge → Centrifuge → Neutr. oil

H3PO4 → RV

NaOH → RV

Water → RV

Dryer → Neutr. oil

Steps:
- Heating
- Lye addition
- Soap separation
- Washing
- Drying
Centrifuge principles
Soap splitting

How to recover fatty acids from the soapstock?

Soap + Sulphuric acid ==> Fatty acid + Sodium sulphate

2 CnHmOONa + H$_2$SO$_4$ ==> 2 CnHmCOOH + Na$_2$SO$_4$

Example: $2 \text{C}_{17}\text{H}_{33}\text{COONa} + \text{H}_2\text{SO}_4$ ==> $2 \text{C}_{17}\text{H}_{33}\text{COOH} + \text{Na}_2\text{SO}_4$

Soap (sodium oleate) + Sulphuric acid ==> Oleic acid (C18) + Sodium sulphate

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Soap splitting line

reactor

soapstock

T-piece

acid

pH

pH

emulsion

separator

acid oil

acid water

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Bleaching

CRUDE TROPICAL ACID DEGUMMED NEUTRALIZED RBD

BLEACHING

DEODORISATION

REFINED OIL

Bleaching earth
Active carbon

Spent bleaching earth
The objective of bleaching

**Reduction of:**

- **Colour**
  - Chlorophyll = green colour
  - Oxidised carotenes = brown colour
- **Phospholips**
- **Metals**
  - Iron
  - Cupper
- **Peroxides**
- **Heavy PAH (using active carbon)**
- **Soap residues from neutralisation**
- **Glycidyl ester**
- **Dirt**
Bleaching earth composition:
- Natural Aluminium hydrosilicate
- 3 % Fe2O3 (= 2 % Fe)
- Natural or Activated by acid to enlarge surface area (50 – 150 m²)

Activated carbon composition:
- Carbonised material with very high internal surface: 500-1500 m²/gr
- Smaller dosage compared to bleaching earth
Bleaching mechanisms

Adsorption: green pigments
Catalytic interactions: degradation oxidised components
Agglomeration: phospholipids, metals
dirt

Filter aid: dirt

Iron agglomerates
Enlarged phospholipid micelles
Bleaching earth
Filter plate
Continuous Two step Bleaching process equipment

**dosing**

sdg/udg Oils, crude Fats, hydrogenated Fats

Steam

Vacuum

F Acid

Dryer

Dynamic mixer

Bleaching earth dosing

Carbon

**bleaching**

Wet Bleacher

Dry Bleacher

**filtration**

Upstream buffer tank

Main Filters

Break tank

Cricket and guard filters

Oil, Steam, Condensate

Steam blowin

To acid oil tank

To sewer

N2

To sewer

Downstream buffer tanks

To deodoriser

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VERTICAL LEAF FILTERS
- Vertical tank
Deodorisation

CRUDE OIL

NEUTRALISATION 90 ºC

BLEACHING 90 ºC

DEODORISATION

REFINED OIL

Steam

Scrubber

Deodoriser distillate

Exhaust Gas

Vacuum system

Waste water

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The objective of deodorization:

• Removal of volatile components
  - Volatile odor and taste substances
  - Free fatty acids
  - Pesticides
  - Light Poly Aromatic Hydrocarbons

• Decomposition of components followed by removal of residues
  - Hydro peroxides (taste/stability)
  - Carotenoids (red color)

• Retain goodies and avoid formation of artifacts
  - Tocopherols
  - Trans Fatty Acids
  - Glycidyl esters
The transfer of a volatile component from oil to steam depends on:
1. Concentration of component in oil
2. Concentration of component in steam bubble
3. The transfer from oil to surface of steam bubble
4. The total surface area of the steam bubbles
5. Temperature
6. Time
Steam stripping theory

• The transfer from oil to steam bubble surface
  • The design of the deodoriser
  • The expansion of the steam bubbles (vacuum pressure)
  • Temperature

• The total surface area of the steam bubbles
  • The steam flow
  • Vacuum pressure
  • Temperature

⇒ The important deodorization parameters are:
  • The steam flow (kg/h)
  • Vacuum pressure (mbar)
  • Temperature (°C)
  • Time (20 minutes – 2 hours)
Deodorization Temperature

A high temperature is required for removal of:

- Volatile odoriferous components
- Free fatty acids
- Pesticides
- Light Polycyclic Aromatic Hydrocarbons
- Decomposition of hydroperoxides
- Heat bleaching
Limitations for a high temperature are

• Construction material

• Side reactions
  • Removal of Tocopherols
  • Partial interesterification (T > 240 °C)
  • Trans fatty acids, Especially from oils containing linolenic acid (C18:3)
  • Glycidyl ester formation

FEDIOL (European O&F producers organisation) defines temperature range 180 – 270 °C for deodorization.
## Effect of temperature on FFA and TFA

<table>
<thead>
<tr>
<th>Oil</th>
<th>Start</th>
<th>180 °C</th>
<th>200 °C</th>
<th>220 °C</th>
<th>240 °C</th>
<th>250 °C</th>
<th>260 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm FFA (%)</td>
<td>5</td>
<td>4.2</td>
<td>3.3</td>
<td>1.7</td>
<td>0.5</td>
<td>0.14</td>
<td>0.05</td>
</tr>
<tr>
<td>Palm TFA (%)</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Rape FFA (%)</td>
<td>1</td>
<td>1.2</td>
<td>1.5</td>
<td>2.5</td>
<td>8</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>Rape TFA (%)</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.5</td>
<td>1.1</td>
<td>1.8</td>
<td>2.9</td>
</tr>
</tbody>
</table>
Batch Deodoriser

Recipe:
- Deaeration
- Heating to deodorization temp.
- Steam dosing at full vacuum
- Cooling to 80 °C
- Pumping/cooling

Storage

Guard Filter

Cooler

Cooling Water

Batch Deodoriser

Recipe:
- Deaeration
- Heating to deodorization temp.
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Cooler

Cooling Water

Batch Deodoriser

Recipe:
- Deaeration
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- Steam dosing at full vacuum
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Storage

Guard Filter

Cooler

Cooling Water
Continuous deodoriser

- Final heating
- Stripping steam
- Pre-treatment
- Citric Acid
- HP steam boiler
- Heater
- Vacuum system
- Cooling water
- Guard filters
- Storage
- Cooler
Refining process routes

**Oil crop**
- Oil extraction
- Water degumming
- Degumming/neutralization
- Bleaching/filtration
- Deodorization (170 – 270 °C)
- Refine oil

**Meal**
- Lecithin purification

**Oil mill**
- Soap splitting
- Steam blowing of filters
- Fatty acid scrubber
- Acid water to effluent treatment
- Condensed steam to effluent treatment
- Vacuum system bleed to effluent treatment
- Acid oil or back to crude
- Deodorizer distillate

**Chemical refining**
- Acid, alkali
- BE, AC
- Steam

**Refining process routes**

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Refining process routes

- **Oil crop**
  - Oil extraction
  - Acid degumming
  - Acid pre-treatment
  - Bleaching/filtration
  - Deodorization (240 – 270 °C)
  - Steam blowing of filters
  - Fatty acid scrubber

- **Physical refining**
  - Steam blowing of filters
  - Fatty acid scrubber
  - Acid oil or back to crude

- **Refined oil**
- **Meal**
- **Sludge**
  - Condensed steam to effluent treatment
  - Deodorizer distillate
  - Vacuum system bleed to effluent treatment

**Citric/Phosphoric acid**
- BE, AC

**Oil mill**

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Refining process routes - chemical versus physical refining

Advantages chemical refining compared to physical:

• Product quality more independent of feedstock quality, can do water degummed oils.
• Lower deodorisation temperatures possible to reduce TFA and Glycidyl esters (T < 240 °C).

Disadvantages:

• Higher oil loss.
• Higher investment (centrifuge line, soapsplitting)
• Higher liquid effluent discharge.
## Specifications refined oils

<table>
<thead>
<tr>
<th>Impurity</th>
<th>Specification</th>
<th>Legislative Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taste &amp; Colour</td>
<td>Bland</td>
<td>Customer specification</td>
</tr>
<tr>
<td>Moisture</td>
<td>Max. 0.05%</td>
<td></td>
</tr>
<tr>
<td>Phosphorous</td>
<td>Max. 5 ppm</td>
<td></td>
</tr>
<tr>
<td>Insolubles</td>
<td>Not visible</td>
<td></td>
</tr>
<tr>
<td>Free fatty acids</td>
<td>Max. 0.1%</td>
<td>MVO guarantee values</td>
</tr>
<tr>
<td>Peroxides</td>
<td>Max. 1.0 meq /kg</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>Max. 0.5 mg/kg</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>Max. 0.05 mg/kg</td>
<td></td>
</tr>
<tr>
<td>Soap</td>
<td>Max. 10 mg/kg</td>
<td></td>
</tr>
</tbody>
</table>
Case:

In which process steps of chemical refining of soybean oil and physical refining of palm oil are the following impurities reduced:

• Free fatty acids
• Peroxides
• Phospholipids
• Metals
• Color
**Refining link table – Impurities**

<table>
<thead>
<tr>
<th>Impurities</th>
<th>Free Fatty Acids</th>
<th>Peroxides</th>
<th>Phosphorus</th>
<th>Dirt</th>
<th>Metals</th>
<th>Taste</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude oil reception</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degumming</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutralization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bleaching</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deodorization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- = Chemical refining
- = Physical refining
- = Both chemical and physical

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Oil Modification
Chemical structure of a triglyceride molecule

Fatty acid 1

Fatty acid 2

Fatty acid 3

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Fatty acid compositions

MUFA

Omega-6

PUFA

SAFA

Canola
Linseed
Sunflower
Corn
Soybean
Olive
Cottonseed
Palm
Palmkernel
Coconut

degree of saturation

CANADA

ASIA

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Solid phase lines

- Butter
- Kitchen Wrapper
- Hot climates
- Soft Tub
- High PUFA

% of solids vs. temp. °C

- Fridge
- Kitchen
- Tropical Climate

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Solid phase lines

Solid Fase Content (SFC) (%)

temperature (deg.C)

- Coconut oil
- Palmkernel oil
- Palm oil
- Sunflower oil

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Optimal solid phase lines

- Solid phase lines for hard fats
- Solid phase lines for spreads
- Solid phase lines for frying oils

Coconut oil
Palmkernel oil
Palm oil
Sunflower oil

MVO - The Netherlands Oils and Fats Industry
Modification toolbox

- BLENDING
  = mixing of oils and fats

- HYDROGENATION
  = saturation of double bonds with hydrogen, saturated fats have a higher melting point
  Partial hydrogenation = part of double bonds saturated  \(\rightarrow\) TRANS
  Full hydrogenation = all double bonds saturated  \(\rightarrow\) NO TRANS

- INTERESTERIFICATION
  = inter-exchange of fatty acid chains in the oil molecules.

- FRACTIONATION
  = crystallisation and separation of the fraction with the higher melting point by filtration
The Normann patent for the hydrogenation of oleic acid (1902)

Dr. Normann's sketch of the lab apparatus, with which he first successfully hydrogenated oleic acid to stearic acid. The title translates as "Conversion of oleic acid to stearic acid". The reactant was in the round-bottomed flask in the centre of the sketch, and the nickel catalyst packed in the neck of this vessel.
Hydrogenation - basics

\[ \text{Linoleic} \xrightarrow{H_2, \text{Ni}} \text{Stearic} \]

\[ \text{Oleic} \]
Hydrogenation – cis and trans

trans-Oleic acid

cis-Oleic acid
<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>Melting Temperature (°C)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C 12:0</td>
<td>30</td>
<td>Lauric Acid</td>
</tr>
<tr>
<td>C 16:0</td>
<td>65</td>
<td>Palmitic Acid</td>
</tr>
<tr>
<td>C 18:0</td>
<td>73</td>
<td>Stearic acid</td>
</tr>
<tr>
<td>C 18:1 cis</td>
<td>5.5</td>
<td>Oleic Acid</td>
</tr>
<tr>
<td>C 18:1 trans</td>
<td>42</td>
<td>trans Oleic Acid</td>
</tr>
<tr>
<td>C 18:2 cis</td>
<td>-13</td>
<td>Linoleic Acid</td>
</tr>
<tr>
<td>C 18:3 cis</td>
<td>-24</td>
<td>Linolenic acid</td>
</tr>
</tbody>
</table>
Trans Fatty Acid formation in Hydrogenation

Trans as function of saturation

Total unsaturates

Ni-S 180
Ni 150 - 180
Ni 120
Example: Palm Oil hydrogenation

![Graph showing the relationship between temperature and solids content for different IV values and trans fats percentages.]

- IV=55, trans=0
- IV=48, trans=35%
- IV=42, trans=30%
- IV=1.5, trans=1.2%

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Fractionation Principles

- Molten fat
- Slurry
- Crystallisation
- Olein
- Stearin
- Solid/liquid separation
- Crystalliser
- Filter

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RBD Oil

Pre-heating 70 °C

Pre-cooling

Cooling to supersaturation

Holding

Filtration

RBD Olein

RBD Stearin

Process block diagram

→ Liquid without crystals

→ Formation of nuclei

→ Crystal growth

→ Separation of crystals from slurry
Membrane filter press

Filling

Squeezing
Solid phase lines - fractionated palm oil

- Palm stearin
- Palm oil
- Palm olein

SFC (%)

temperature (deg.C)
Products from palm oil fractionation

- **Palm Oil**
  - **Stearin**: 20%
  - **Olein**: 80%

  - **Stearin**
    - Super Stearin: 40%
    - Mid Stearin: 60%

  - **Olein**
    - Soft Mid Fraction: 50%
    - Super Olein: 50%

  - **Soft Mid Fraction**: 40%
  - **Mid Olein**: 60%
Interesterification – random distribution

1 2 3 + catalyst

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Solid Phase lines of interesterified palm kernel oil and palm stearin

Temperature (C)

Solids (%)

- Palmkernel
- Palm stearin
- 60POs/40PK
- in(60POs/40PK)

Interesterification
**Chemical Interesterification**

**Components** + catalyst → **Interesterified mixture**

**Process characteristics:**
- **Catalyst:** Sodium Methylate, toxic, highly inflammable, corrosive.
- **Process:** Batch, temperature 110 °C, fast and complete reaction.
- **By-Products:** Soap (effluent) + methylesters (high temperature stripping)
  Hazardous by-products at too high temperature and/or catalyst overdosing
  T (max) = 110 °C, Catalyst (max) = 0.12 %
  Interesterification must be followed by bleaching and deodorization.
- **Product:** Fully determined by fatty acid composition of input oils
Chemical Interesterification batch vessel
Enzymatic interesterification

Components

Enzyme

Interesterified mixture

Process characteristics:
- Enzyme: GMO Lipase (Novozymes), Food grade (Kosher, Halal). Immobilized in fixed bed.
- Process: Continuous, temperature 40 – 70 °C, slow and incomplete reaction.
- By-Products: No by-products
- Product: Determined by components and process
Packed Bed Reactor (PBR)
Case:

Give the combination of process steps for the production of trans-free hard fat starting from:

1. Palm oil and palm kernel oil
2. Soybean oil
Trans free hardstock production

Liquid oils

Tropical oils

Full Hydrogenation

Interesterification

Fractionation

TFA-free fat-phase component

Trans free hardstock production