IChemE

Palm Oil Processing
Special Interest Group

# Introduction to Oleochemicals

18th September 2017

Monash University Malaysia

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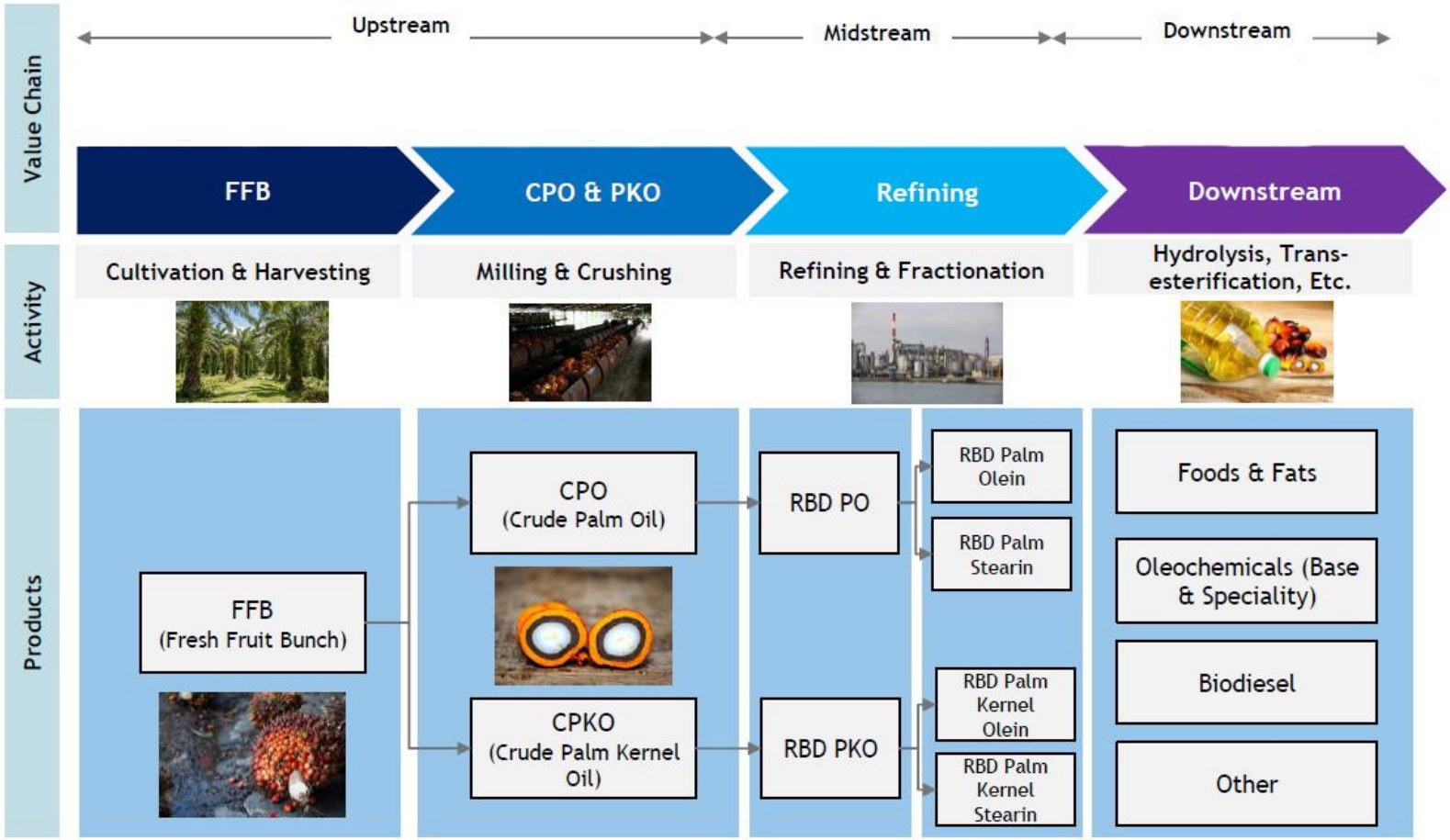
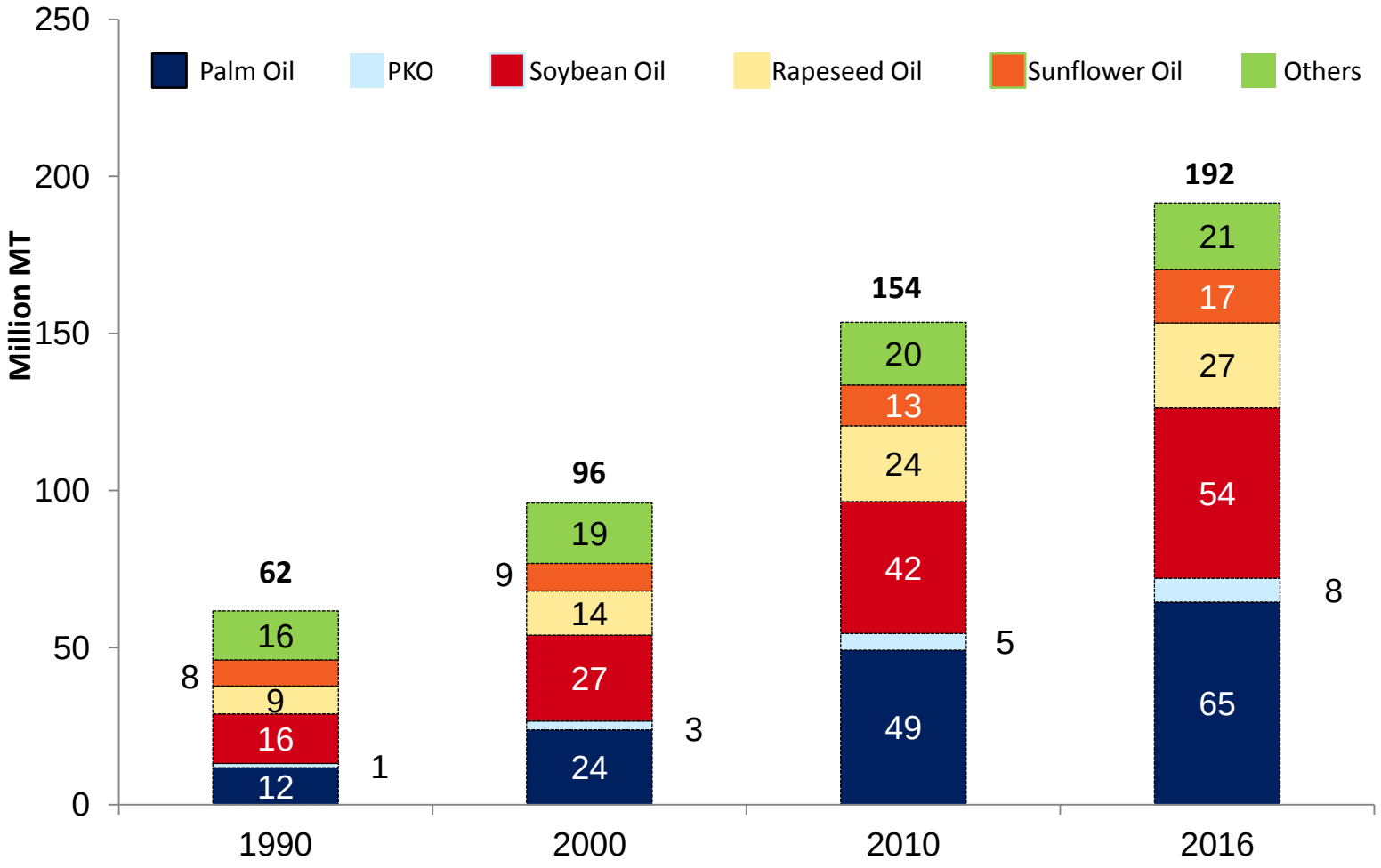
# PO & PKO supply chain



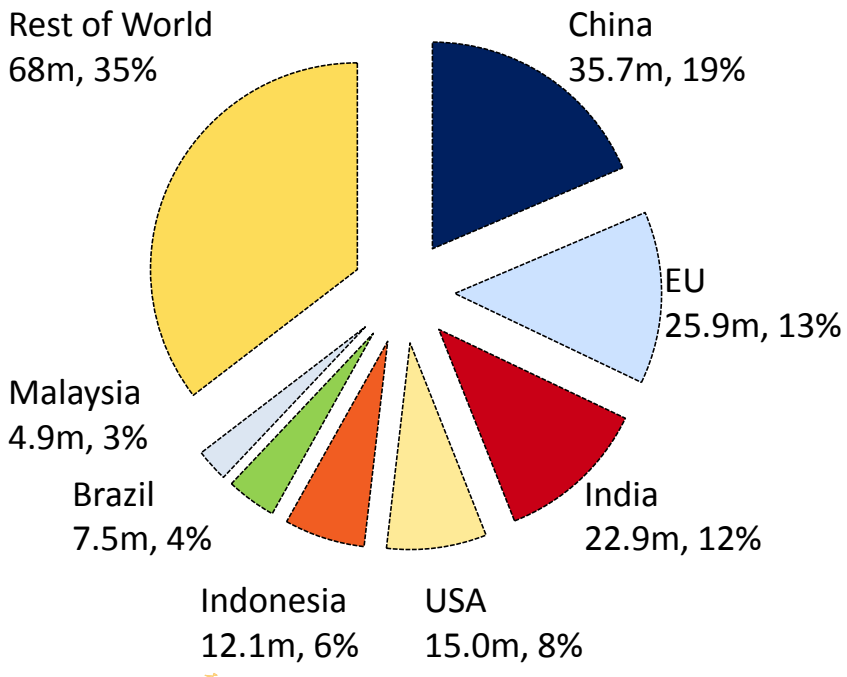
# What will be covered

1. Vegetable Oil Market
2. Oleochemistry
3. Oleochemicals
4. Oleochemical Market

# 1. Global Vegetable Oil Production

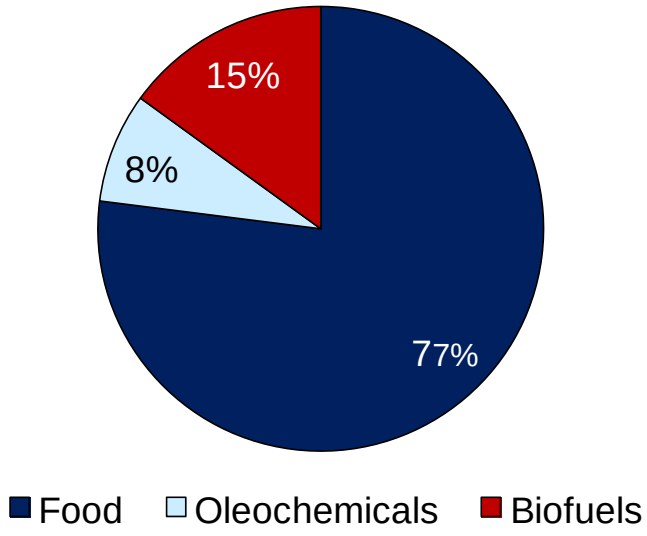


# Market Share by Region, 2016

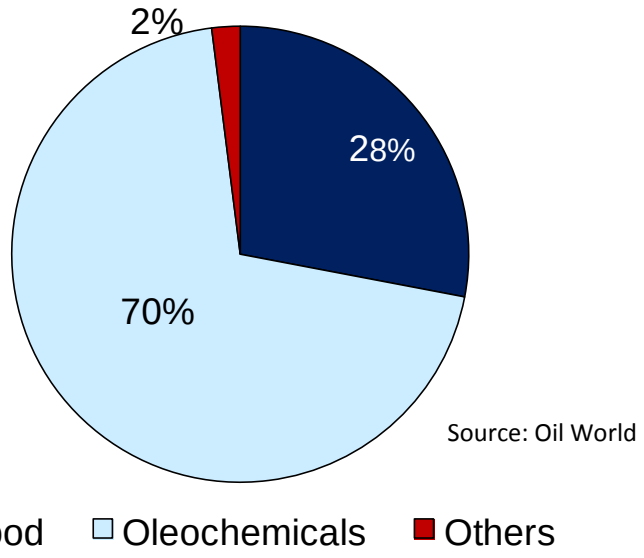


# Where PO and PK is used

**Global Palm Oil Consumption – Split by Applications, 2016**



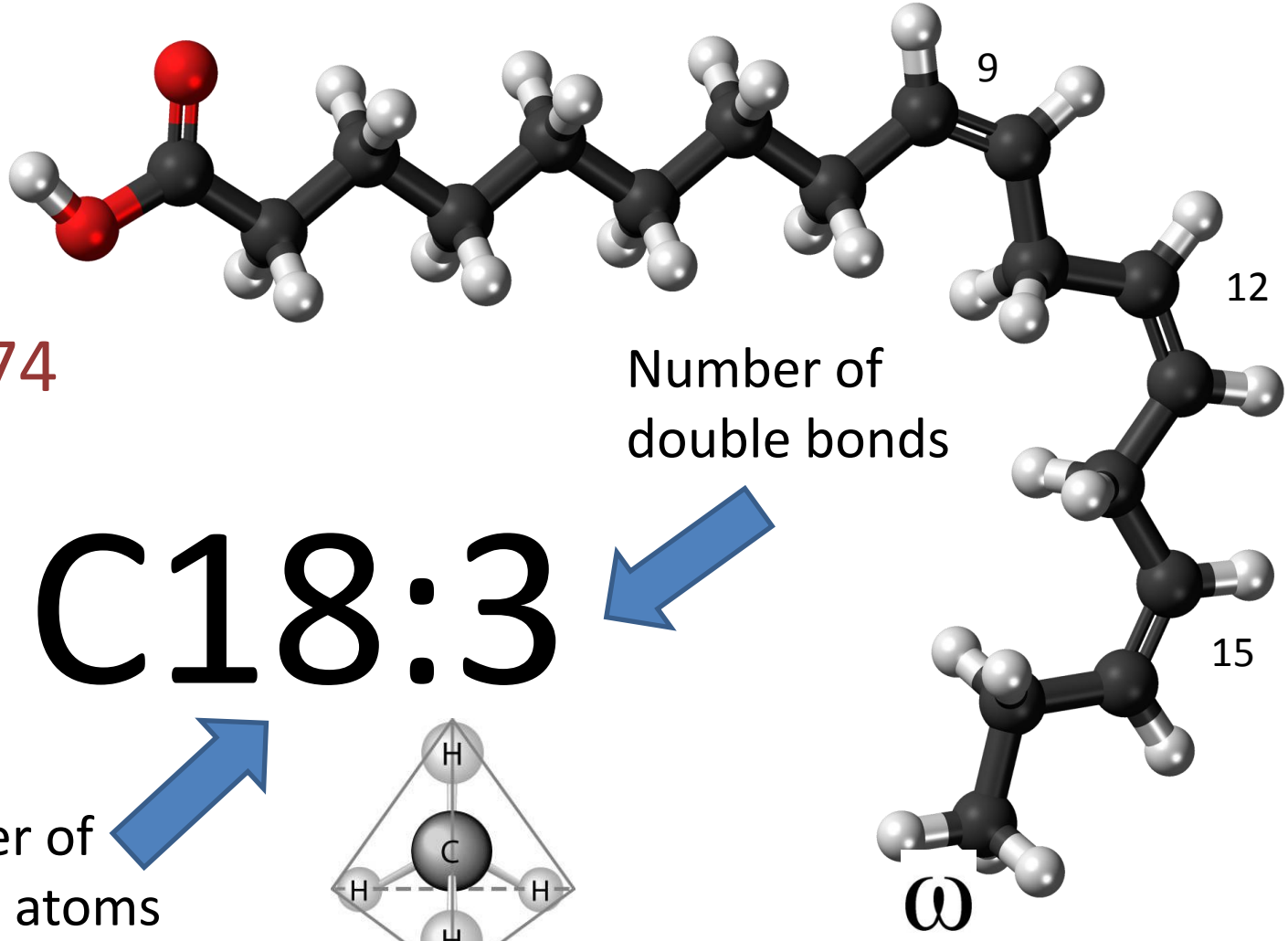

**Global Palm Kernel Oil Consumption – Split by Applications, 2016**



# 2. Oleochemistry

- What is a fatty acid
- The structure of triglycerides
- SAFA, MUFA, PUFA, Omega-3
- Trans Fatty Acids
- Composition of selected oils

# Understanding a fatty acid molecule




IV=274

Number of double bonds

C18:3

Number of carbon atoms

# The fatty acids in palm oil

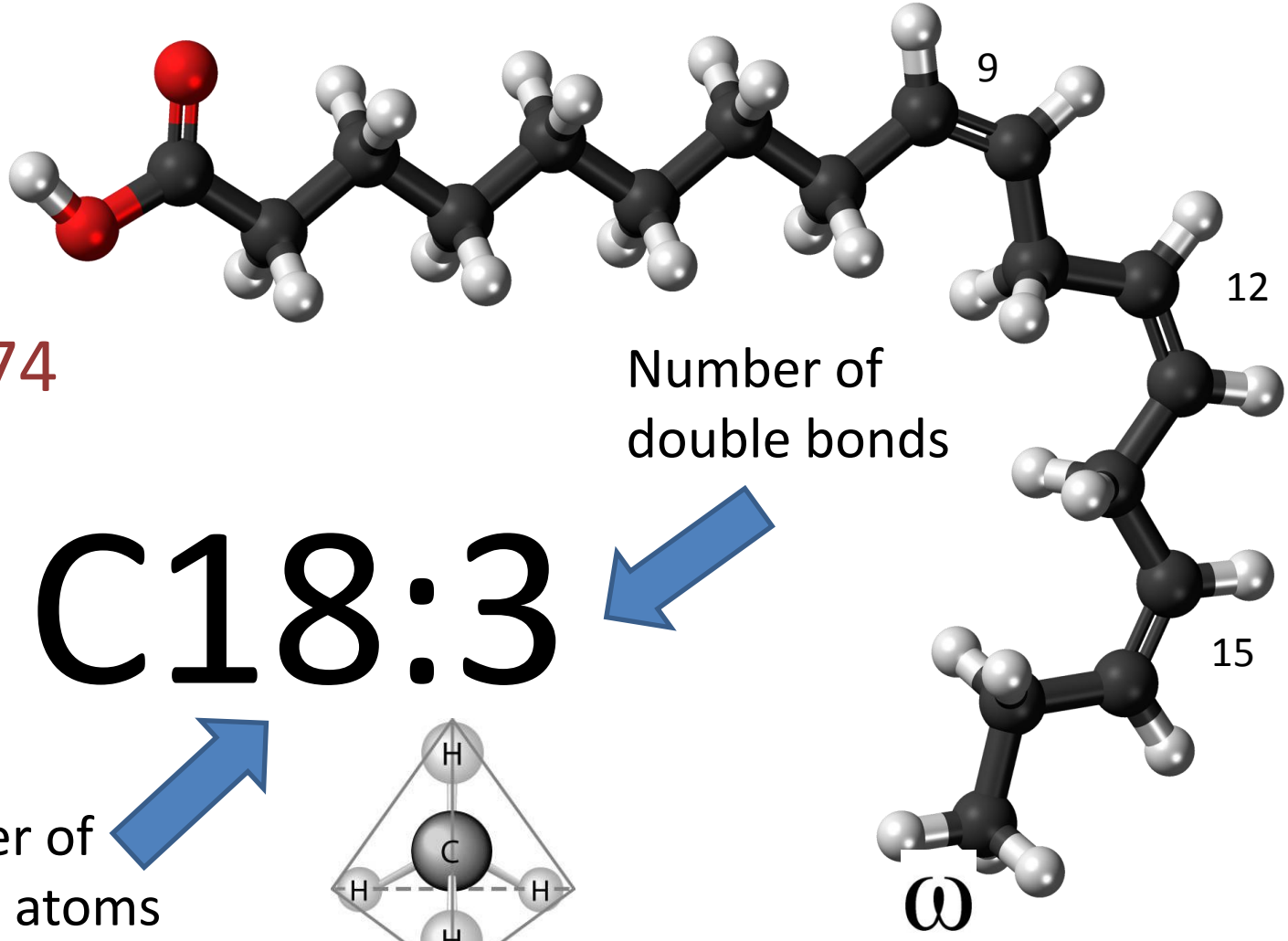
**C8 to C16**

- C8:0
- C10:0
- C12:0
- C14:0
- C16:0

**C18**

- C18:0
- C18:1
- C18:2
- C18:3

# Understanding a fatty acid molecule



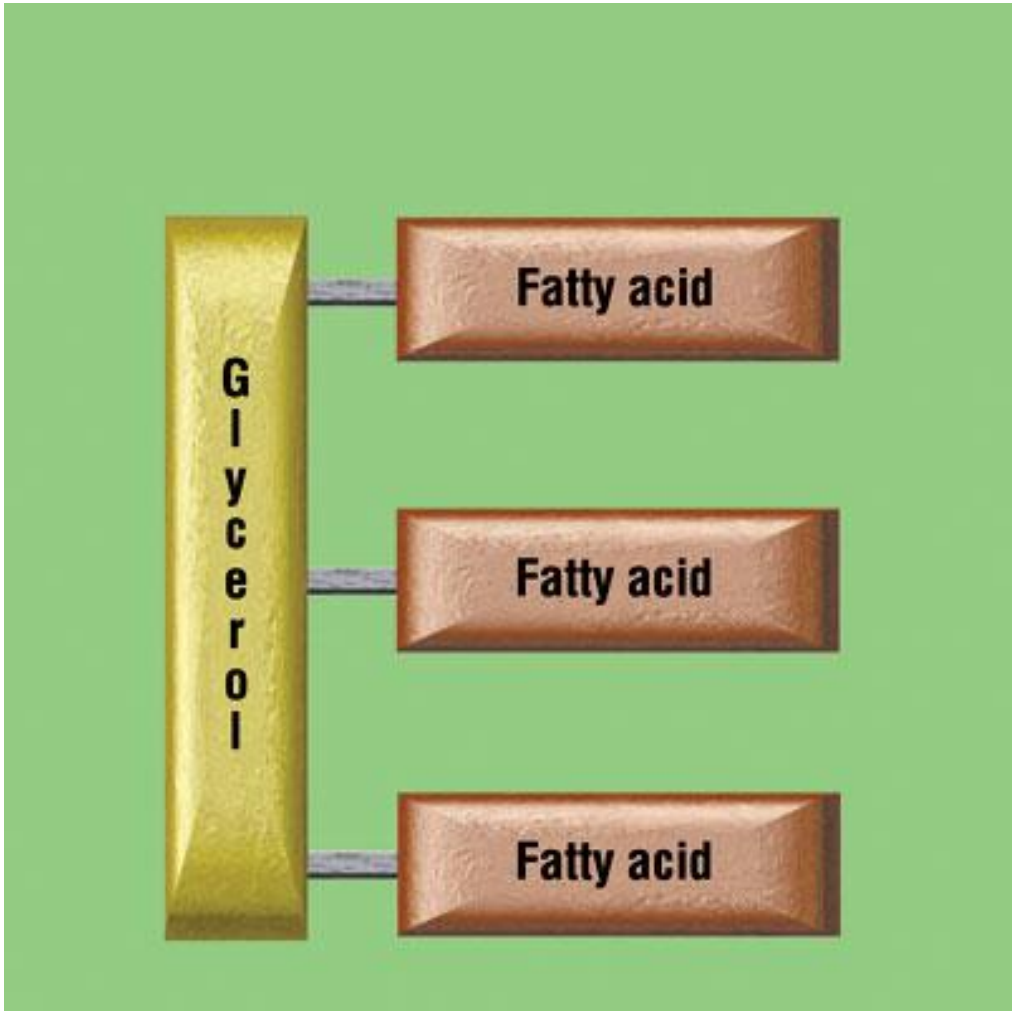

IV=274

Number of double bonds

C18:3

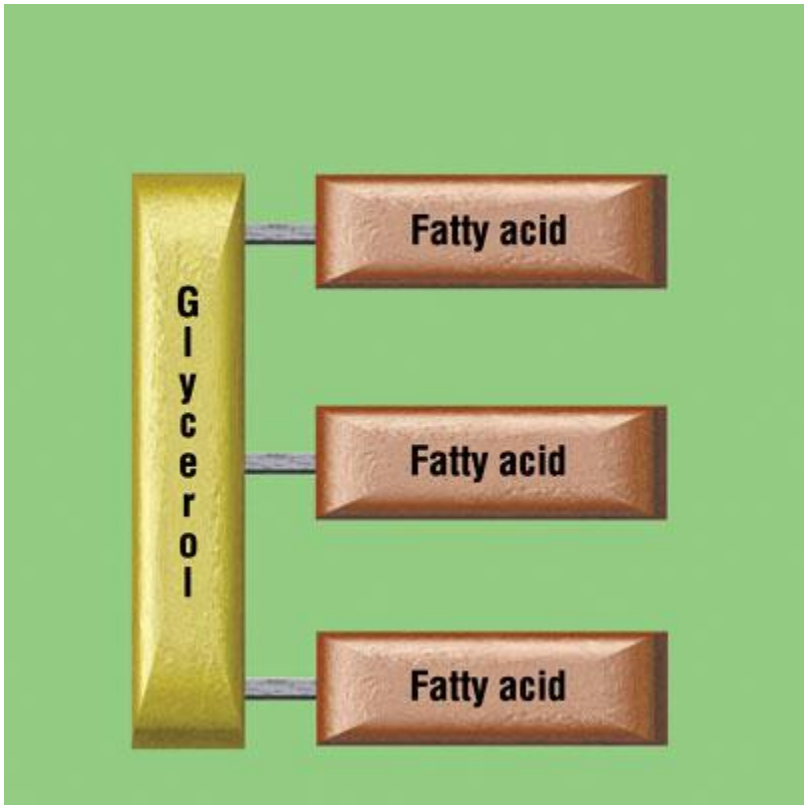
Number of carbon atoms

# Structure of triglyceride



# Placement of fatty acids in PO

(40 possible combinations)



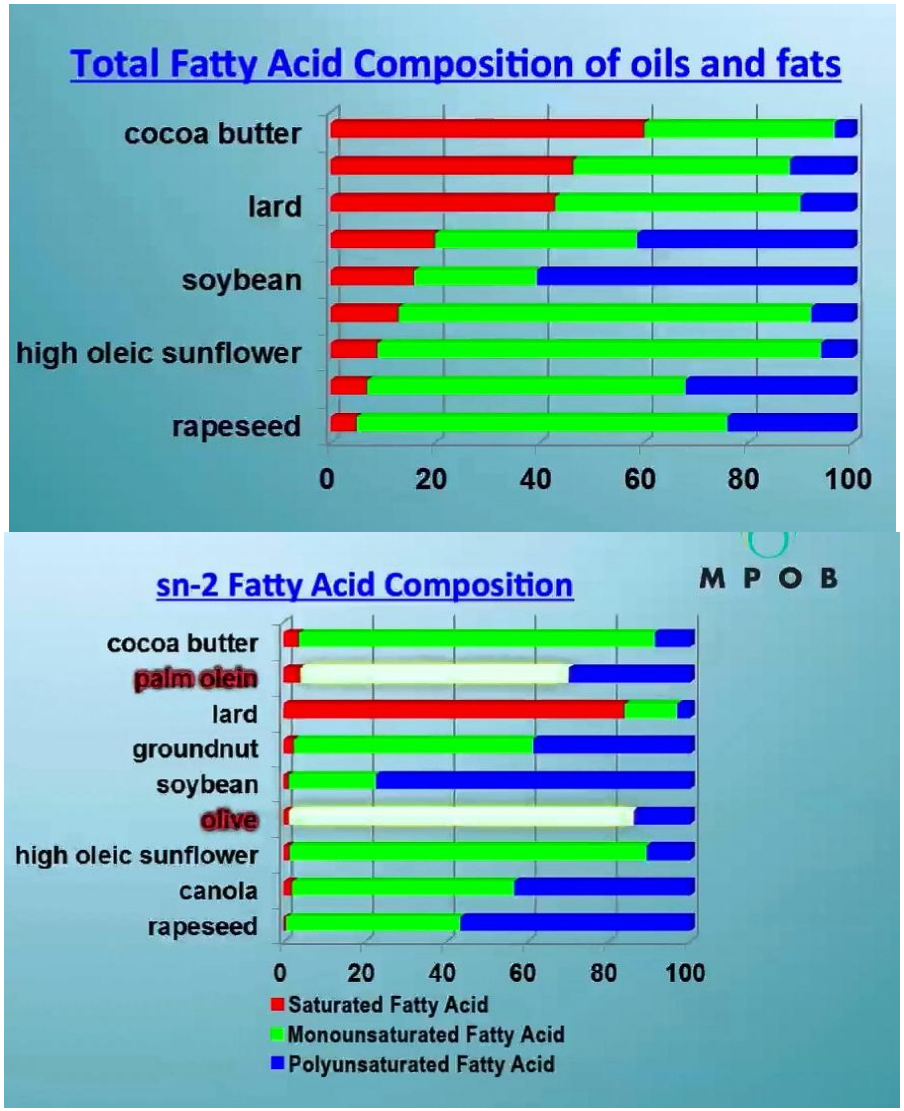

eg. POP at 23.7%

sn-1 Palmitic 16:0

sn-2 Oleic 18:1 (n-9)

sn-3 Palmitic 16:0

# Palm Olein behaves more like Olive Oil




Oleic acid situated at sn-2 has neutral influence on cholesterol levels.

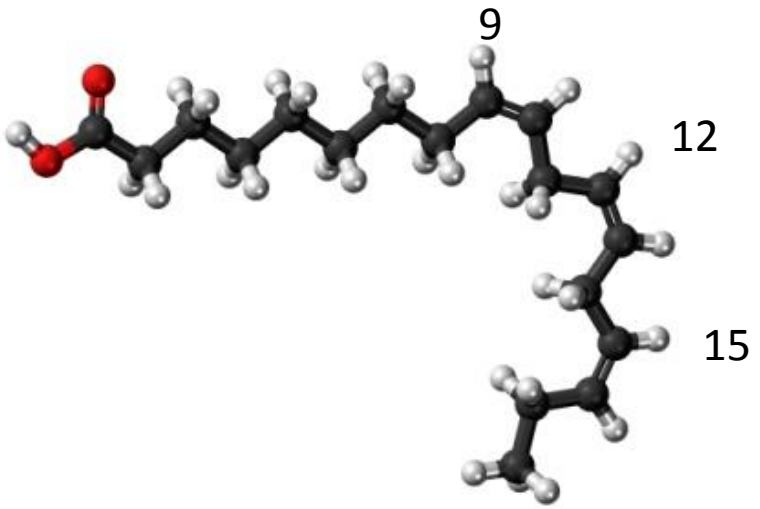
Palmitic acid at the first and third positions tend to exhibit lower fat deposition in the body

## Molecular structure fatty acids

# PUFA

**Polyunsaturated Fatty Acid**

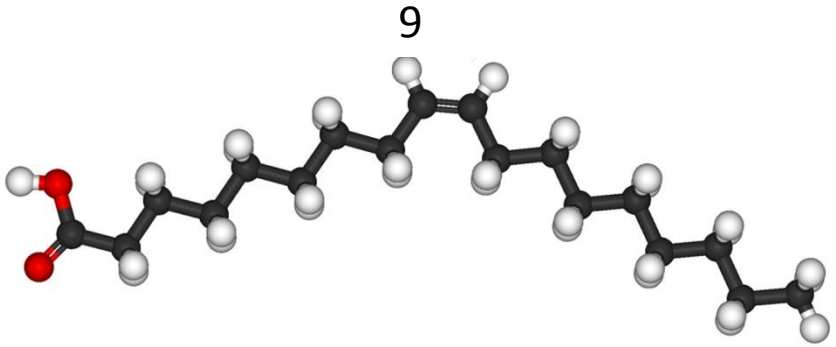
*9,12,15-octadecatrienoic*
*or α-linolenic 18:3(n-3)*




# MUFA

**Monounsaturated Fatty Acid**

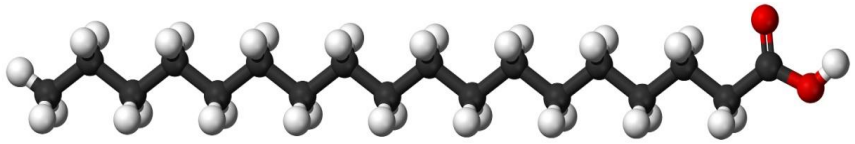
*oleic acid 18:1 (n9)*




# SAFA

**Saturated Fatty Acid**

*stearic acid 18:0*



# Omega fatty acids

- Omega-3 (EPA & DHA) and Omega-6 are EFAs (essential fatty acids)
- Protect our hearts, joints, pancreas, mood stability and skin
- Too much Omega-6 eg in corn oil can raise BP

| Common name | Lipid name | Chemical name |
|---|---|---|
| α-Linolenic acid (ALA) | 18:3 (*n*-3) | *all-cis*-9,12,15-octadecatrienoic acid |
| Eicosapentaenoic acid (EPA) | 20:5 (*n*-3) | *all-cis*-5,8,11,14,17-eicosapentaenoic acid |
| Docosahexaenoic acid (DHA) | 22:6 (*n*-3) | *all-cis*-4,7,10,13,16,19-docosahexaenoic acid |

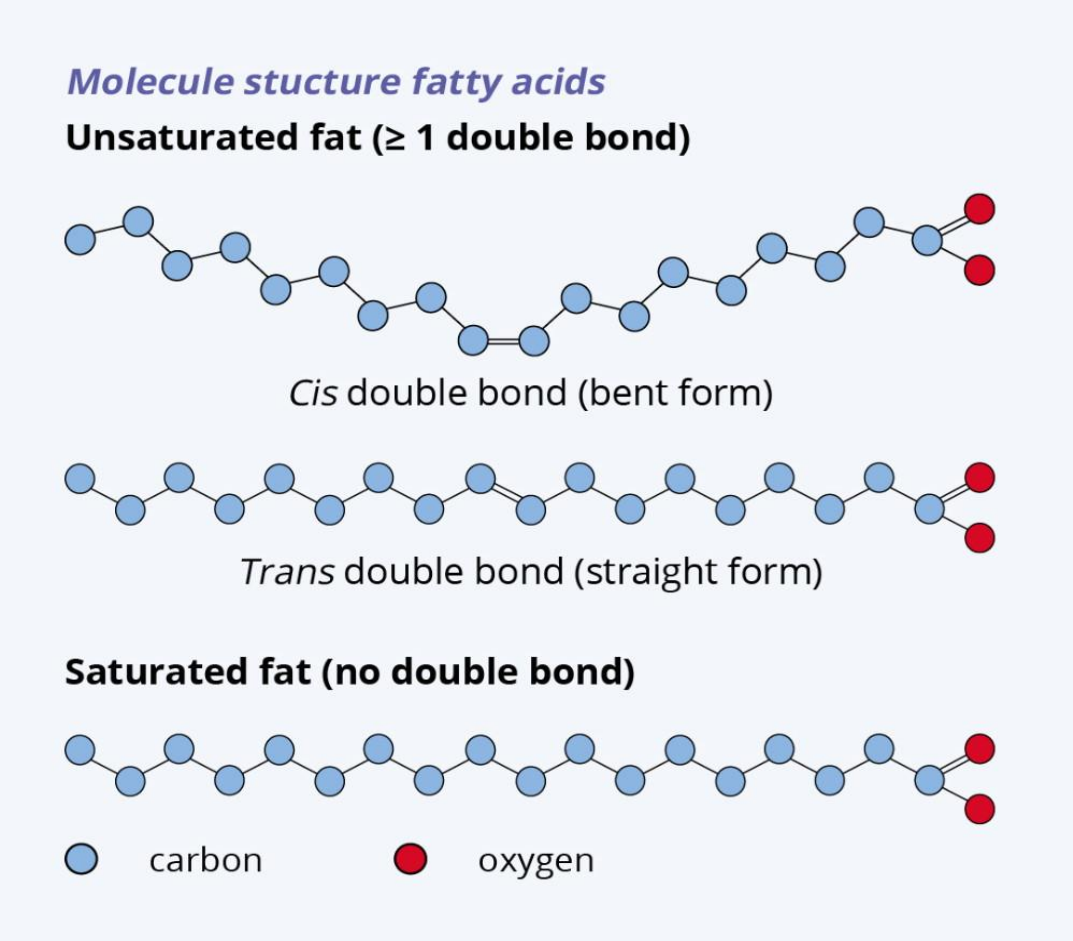
# TFA

**(Trans Fatty Acids)**

**Oleic acid 18:1 (n-9c)**

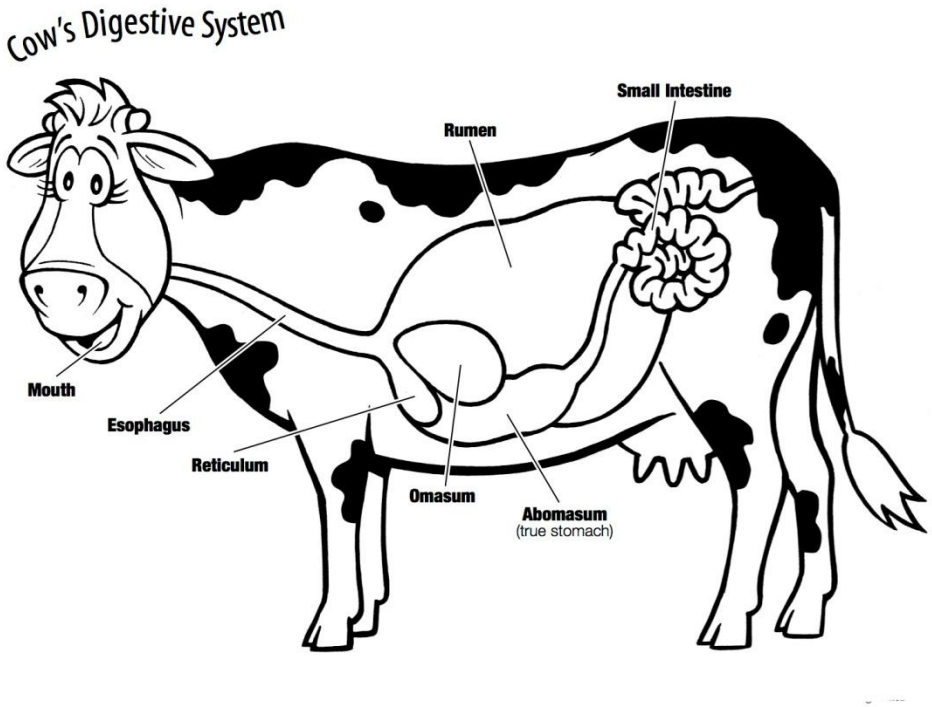
**Elaidic acid 18:1 (n-9t)**

**Stearic acid 18:0**




Trans (unsaturated) fatty acid is a result of the hydrogenation process. It increases the risk of developing heart disease and stroke

# Natural Trans Fat




One stomach with 4 compartments viz rumen, reticulum, omasum and abomasum

The digestion process, particularly the stomach bacteria, in ruminant animals naturally adds hydrogen in the rumen.

Conjugated linoleic acid (mainly 9-*cis*, 11-*trans*-octadecadienoate) is present in butter (ca 3%). There have not been sufficient studies to determine whether these naturally occurring *trans* fats have the same bad effects on cholesterol levels as *trans* fats that have been industrially manufactured.

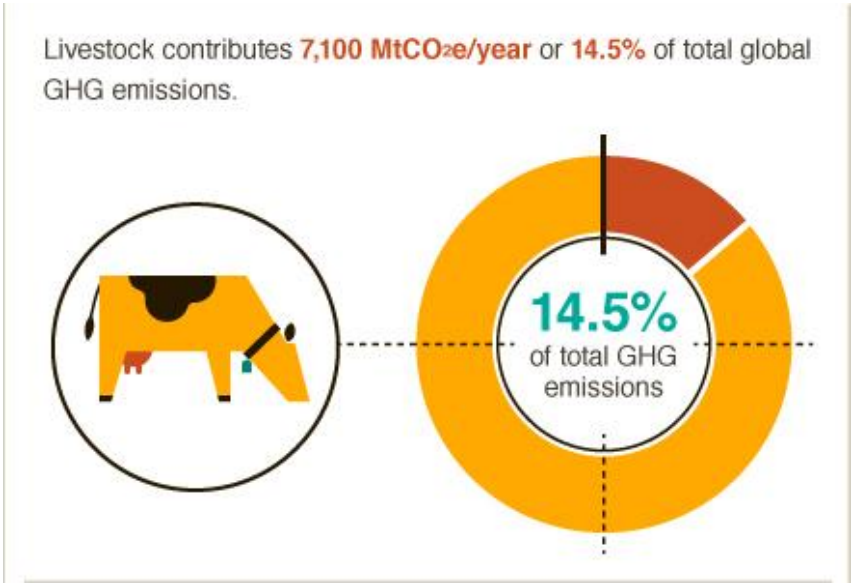
Trans Fat in margarine* is ca 15% and palm based margarine is <1%.
*from soft oils

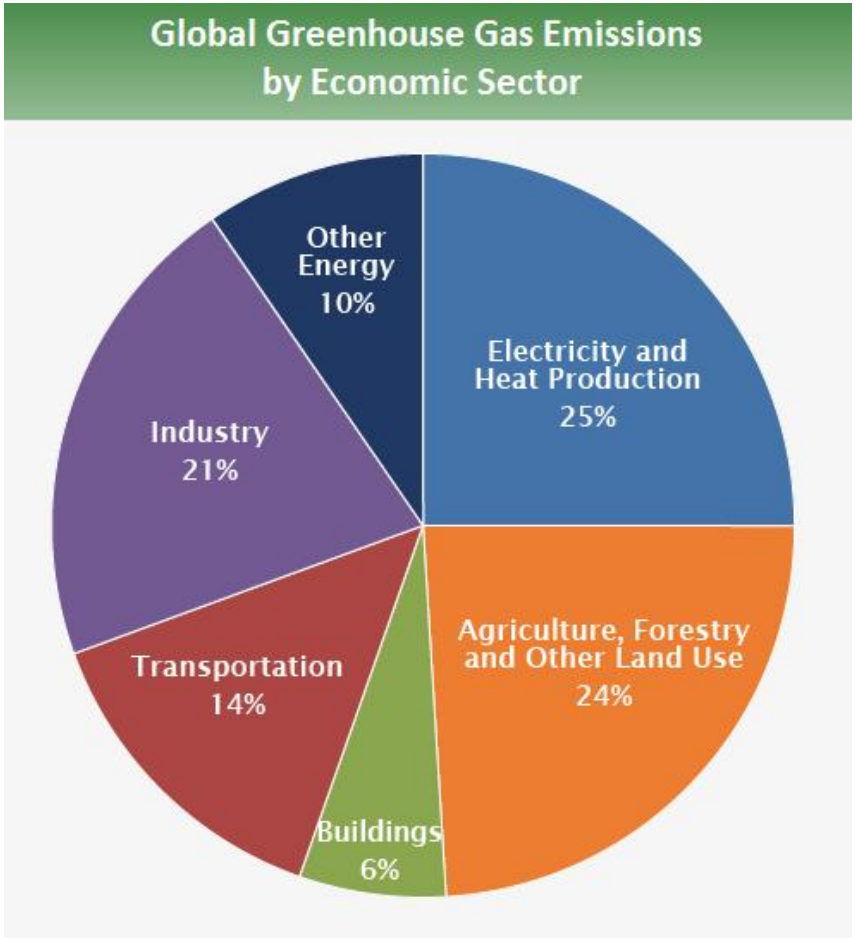
# Cows fart & burp methane

- Microbes in their stomach break down their food into methane as a byproduct
- One cow = one car. 1.5 billion cows and bulls
- Forest cover is cut for grazing pastures

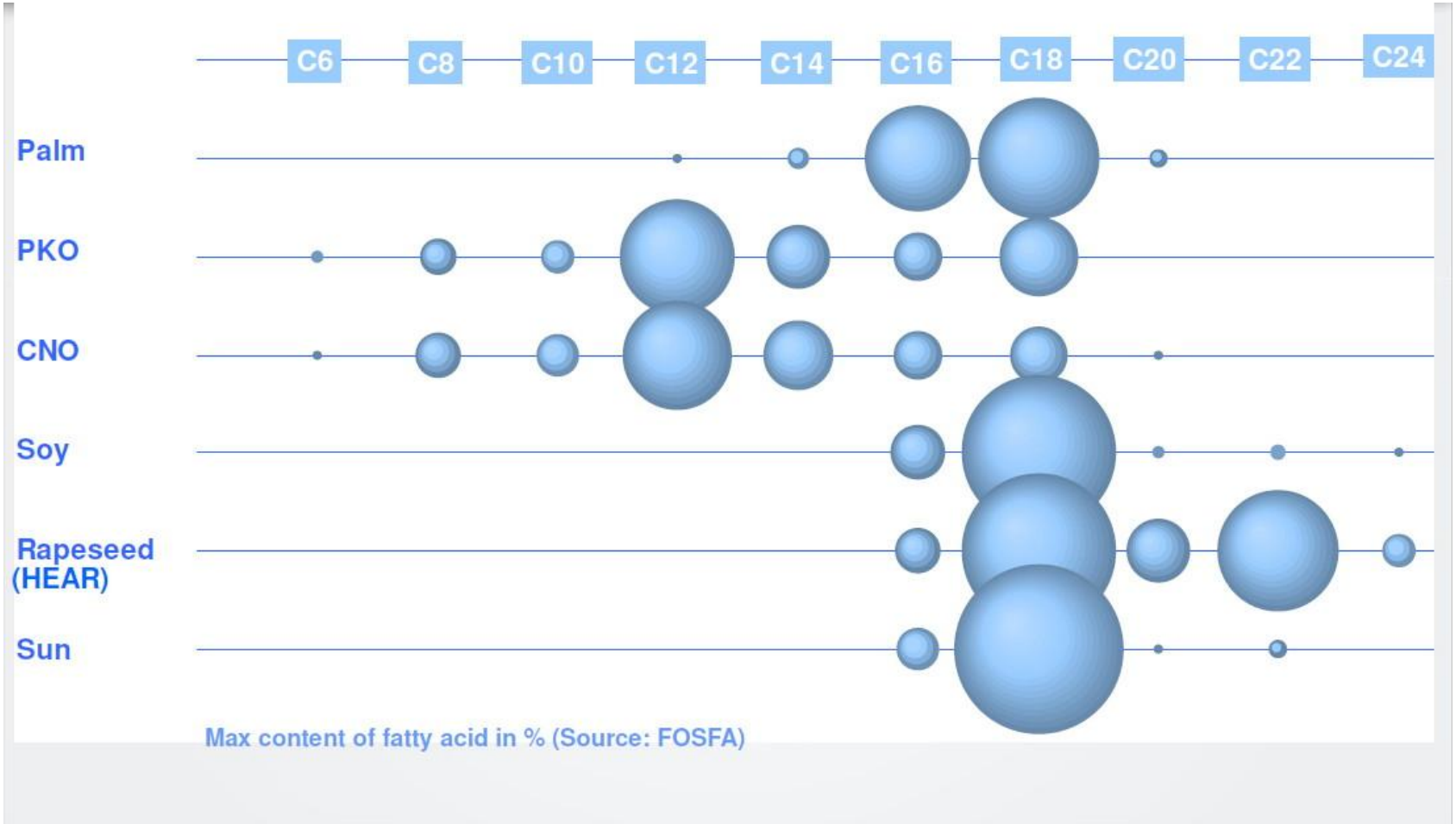
  We trap our methane!
- Biomethane from anaerobic digestion of POME is used for heating and power generation

# Global GHG Emissions

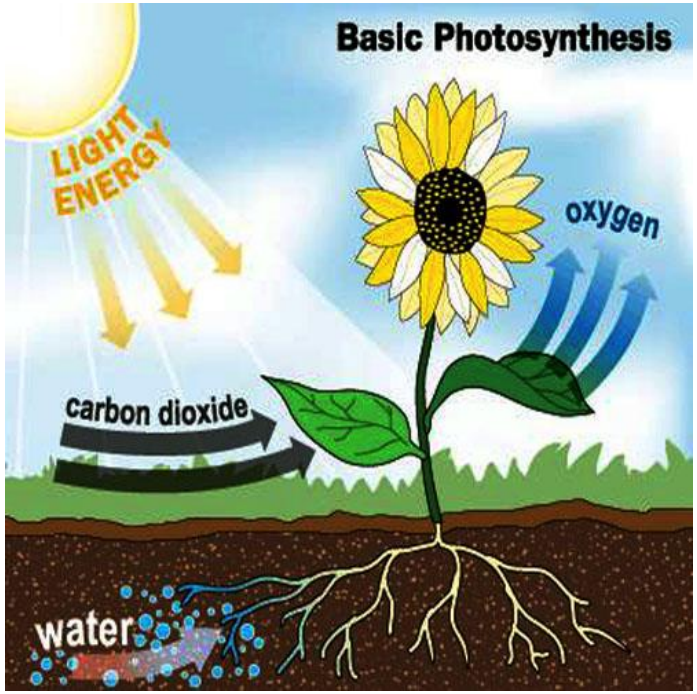


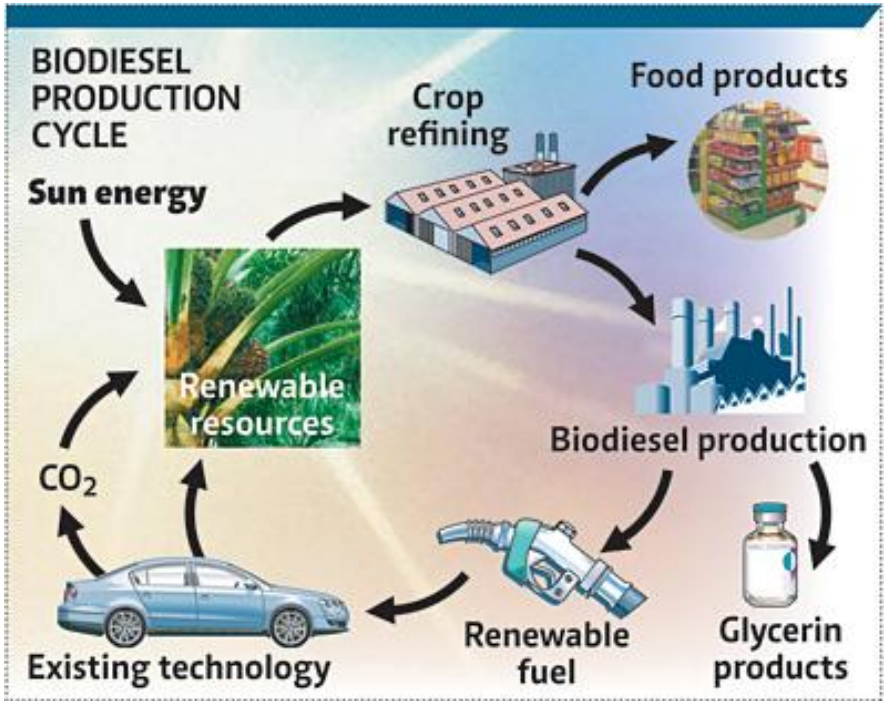



# Composition of selected oils



# How oleochemicals is green



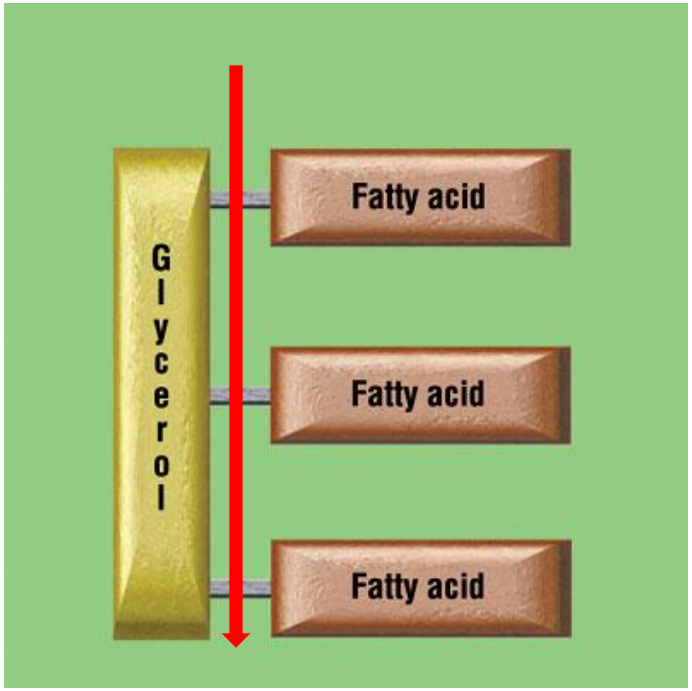



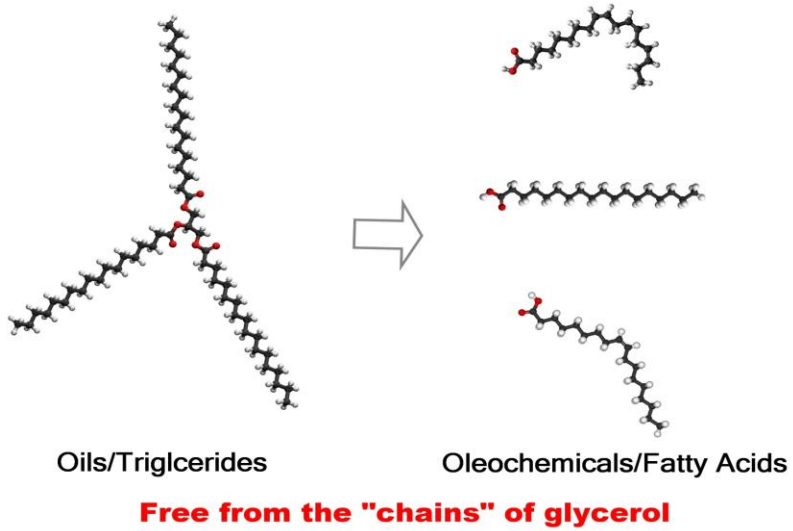
# 3.Oleochemicals

- What are oleochemicals?
- Oleochemical processes
- Oleochemicals in your shower cream
- Oleochemicals in your daily life
- An interesting oleochemical
- Bio-processes
- Metathesis

# What are oleochemicals?

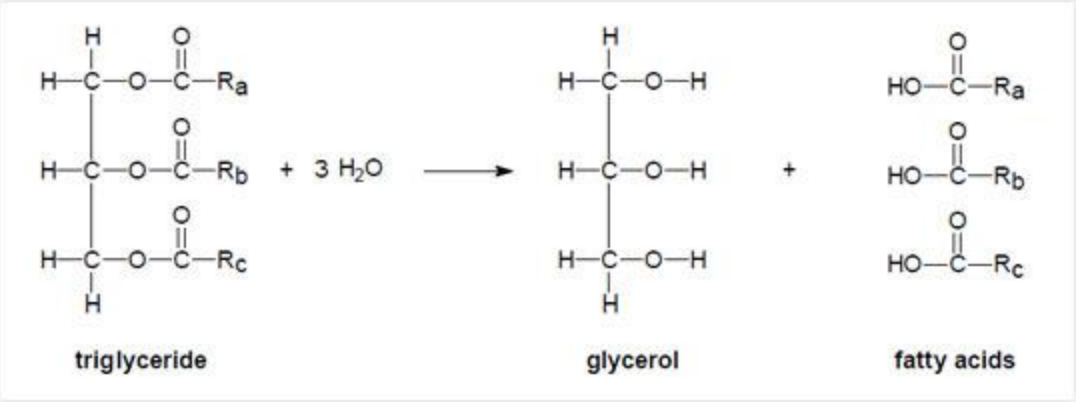
Oleochemicals (from Latin: oleum “olive oil”) are chemicals derived from plant and animal fats. They are analogous to petrochemicals derived from petroleum



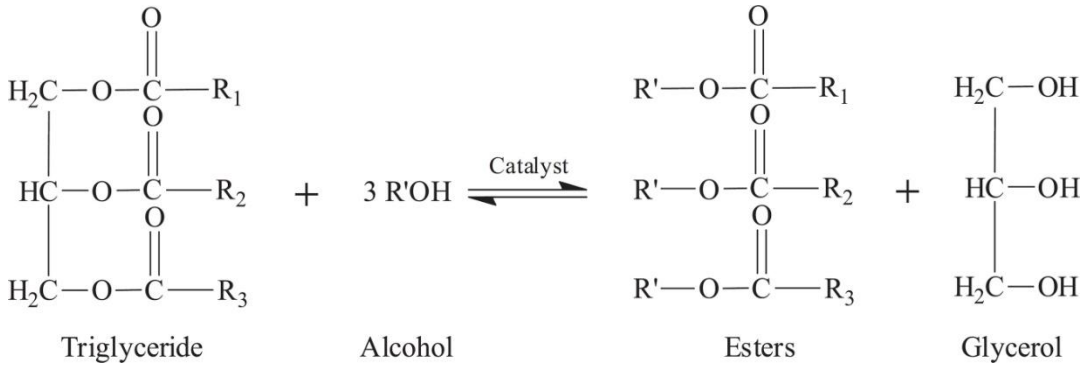




Versatility

# Gateways to oleochemicals



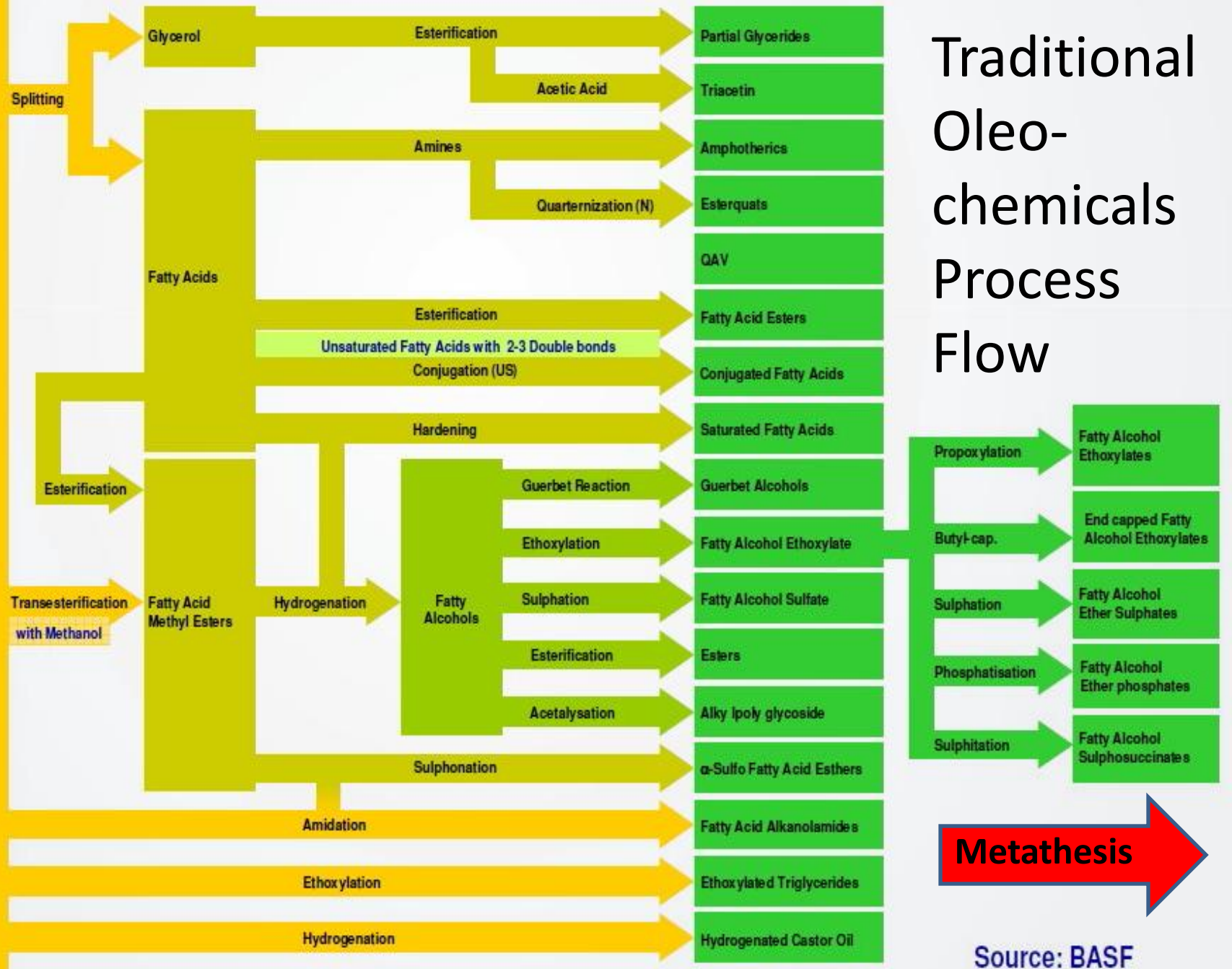

Splitting (hydrolysis)




Transesterification

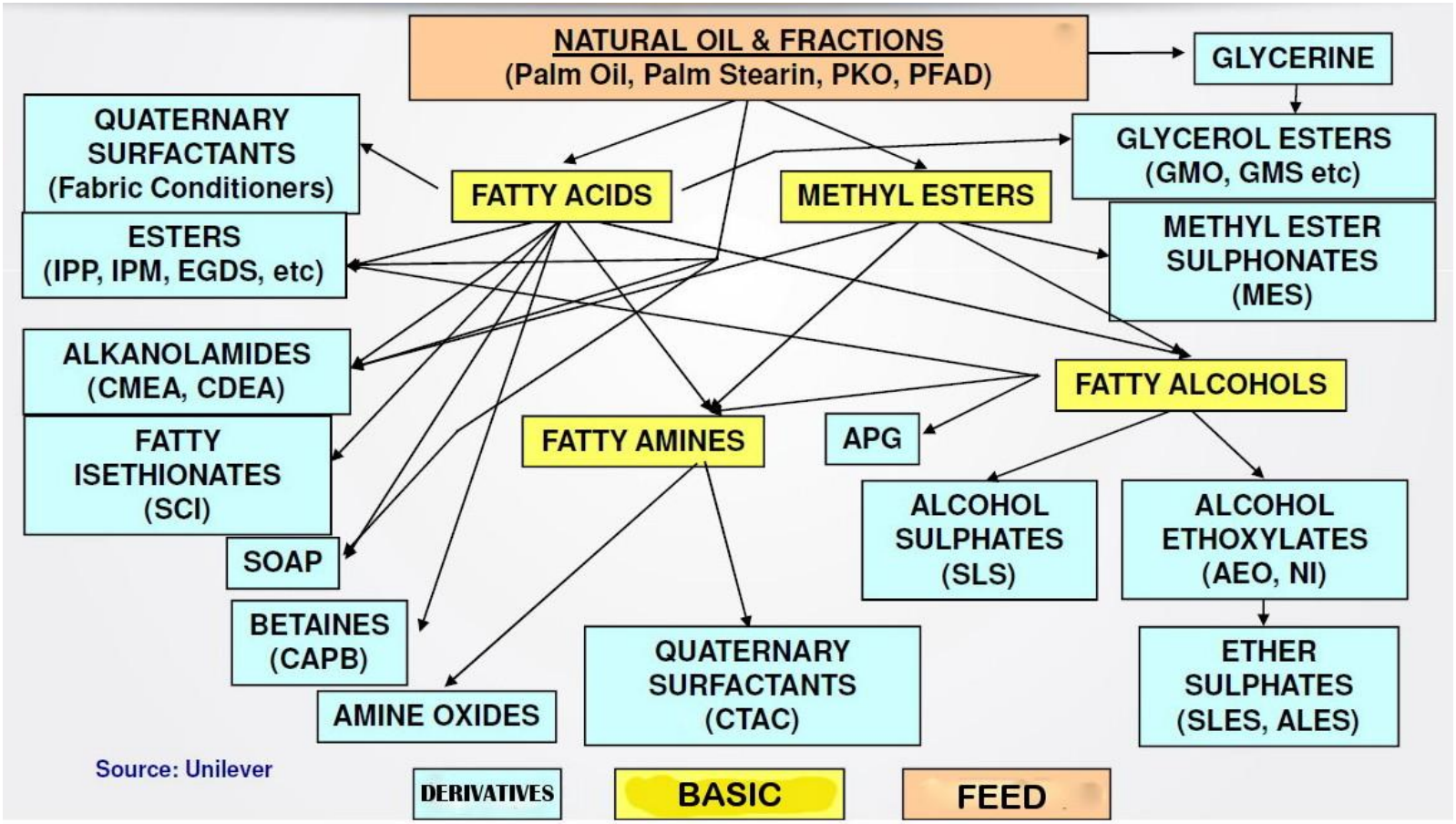
Palm oil Methanol Biodiesel Glycerol

# Traditional Oleo-chemicals Process Flow

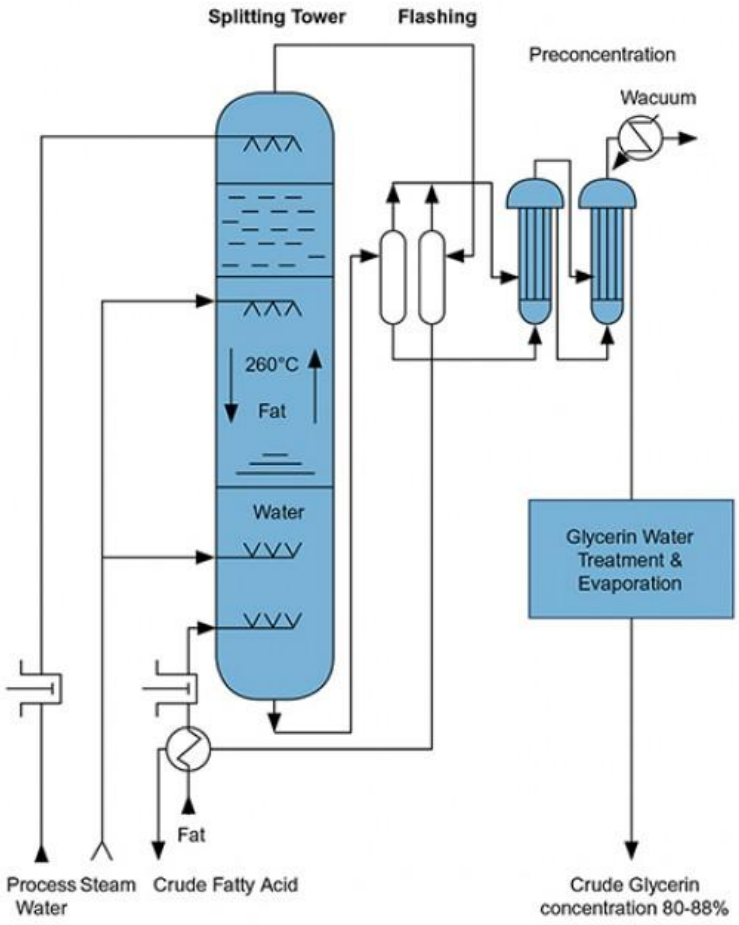



Source: BASF

# Complex or Versatile?



# Splitting


Splitting Tower
Flashing
Preconcentration
Wacuum
260°C
Fat
Water
Glycerin Water Treatment & Evaporation
Fat
Process Steam Water
Crude Fatty Acid
Crude Glycerin concentration 80-88%

# Transesterification

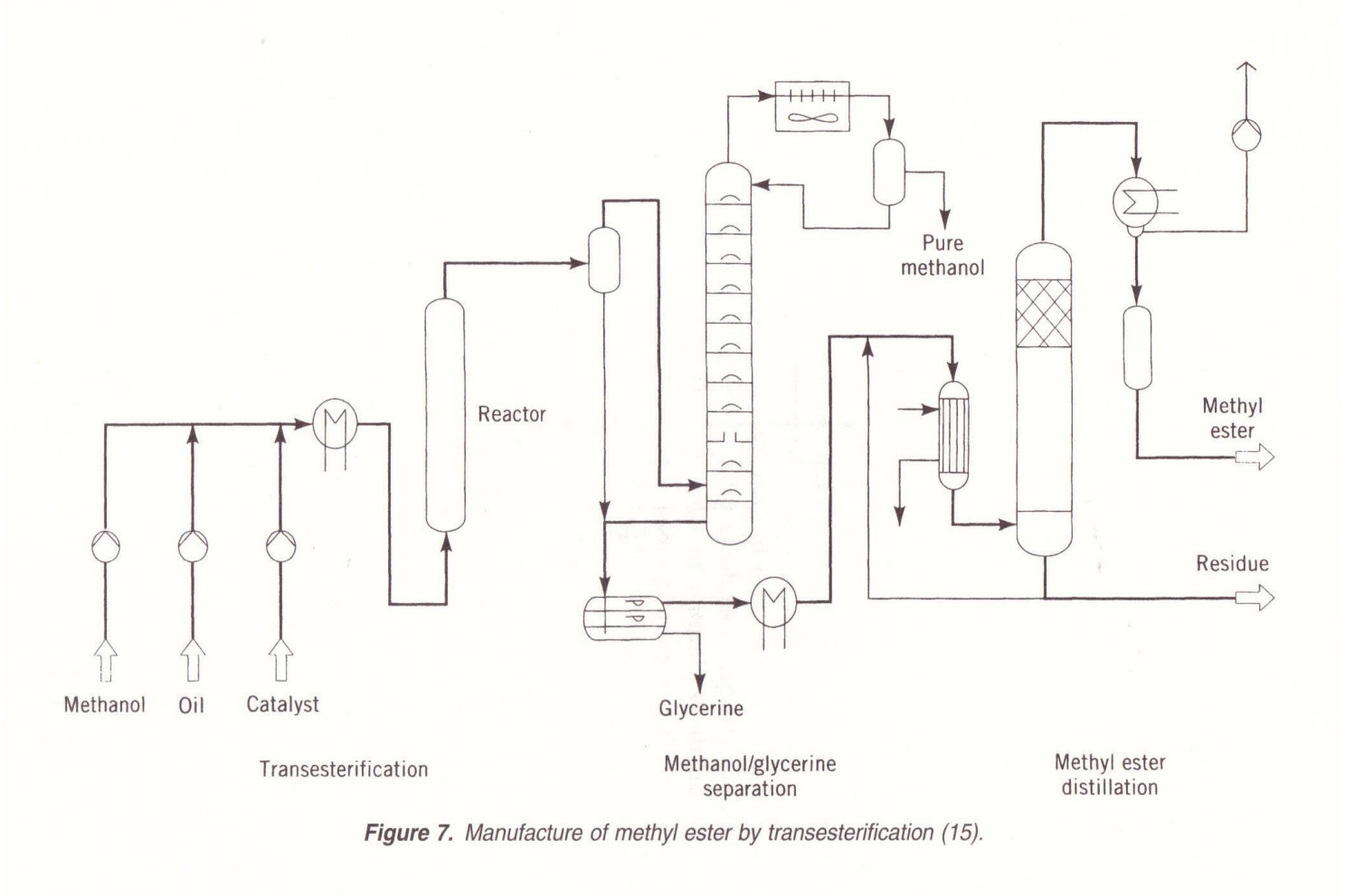
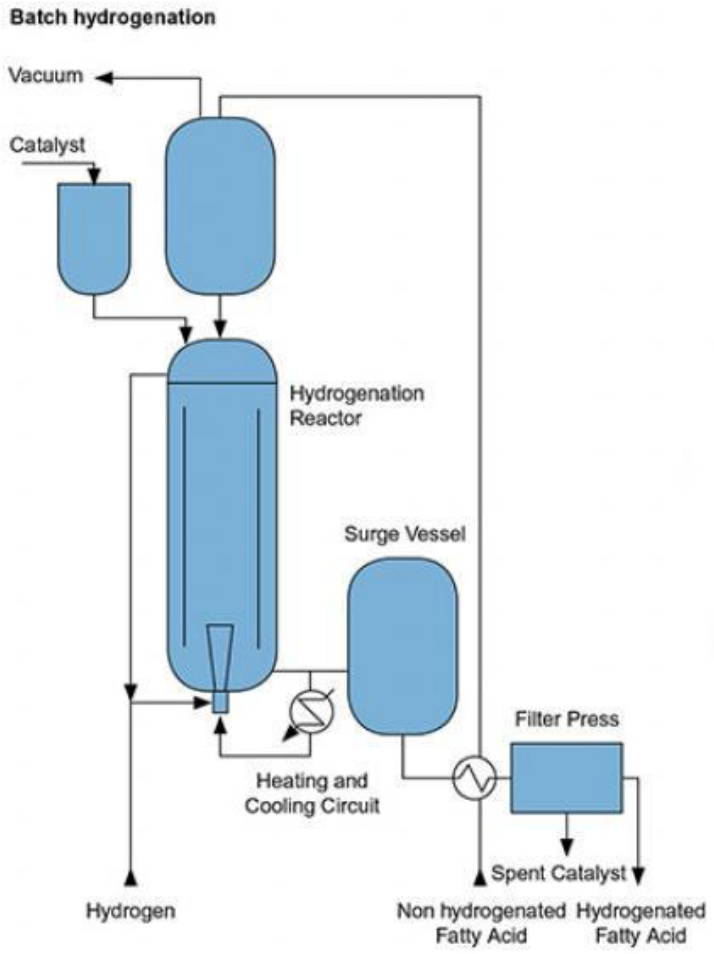


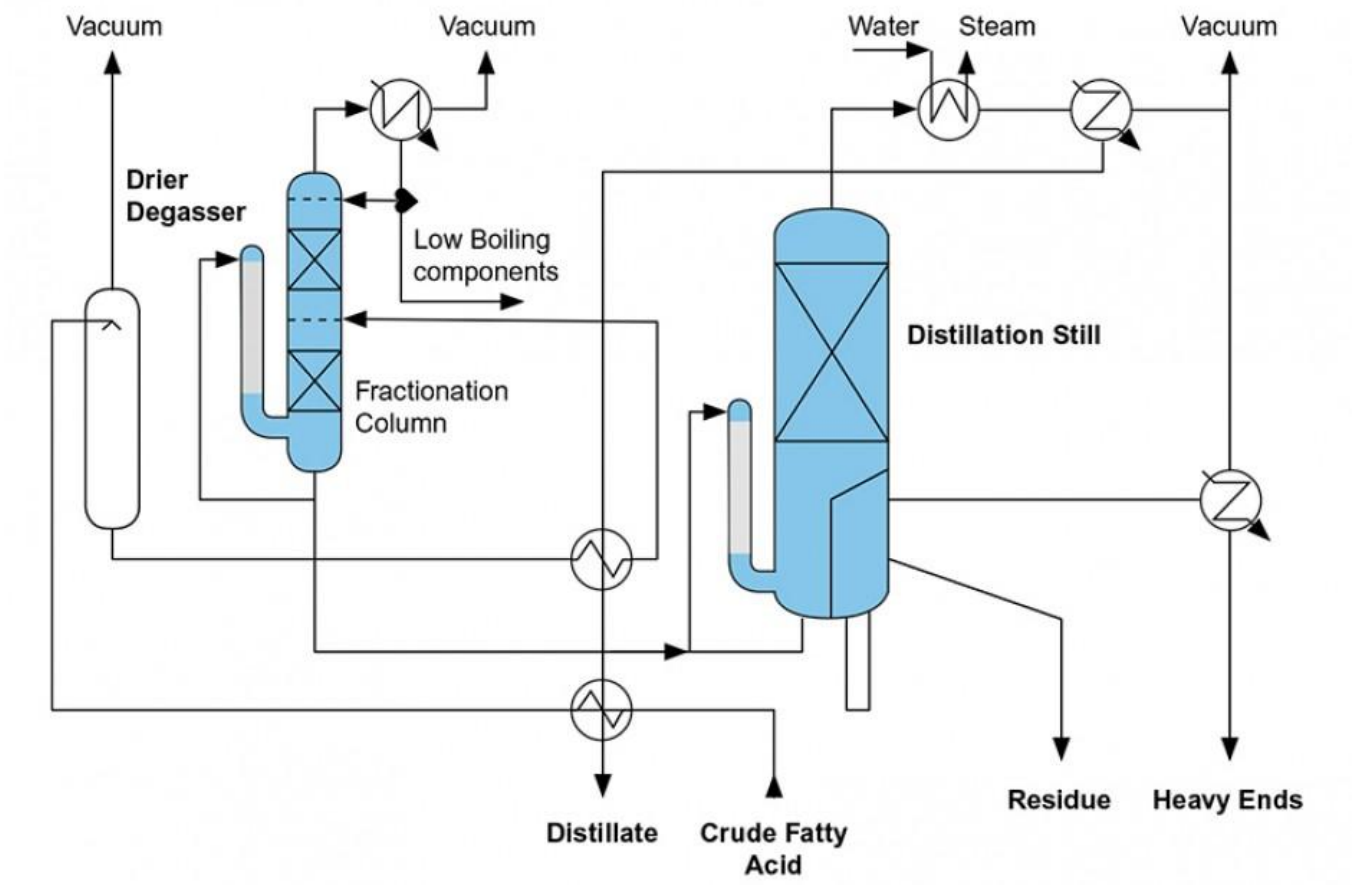

***Figure 7.*** *Manufacture of methyl ester by transesterification (15).*

# Hydrogenation of fatty acids

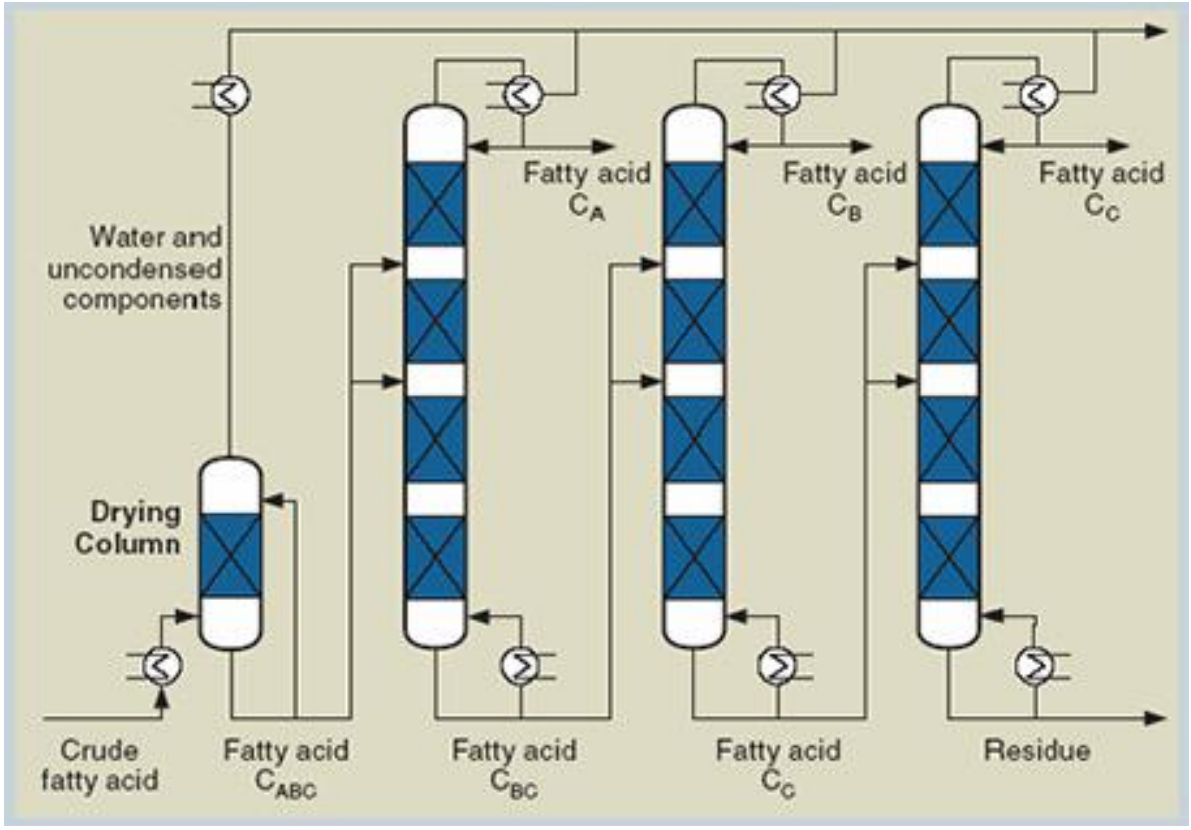



| Ester | | Configuration | Melting Point |
|---|---|---|---|
| Linolenic | C18:3 | Three double bonds | -13C |
| Linoleic | C18:2 | Two double bonds | -7C |
| Oleic | C18:1 | One double bond | 16C |
| Stearic | C18:0 | No double bonds | 70C |

# Distillation



# Fractionation

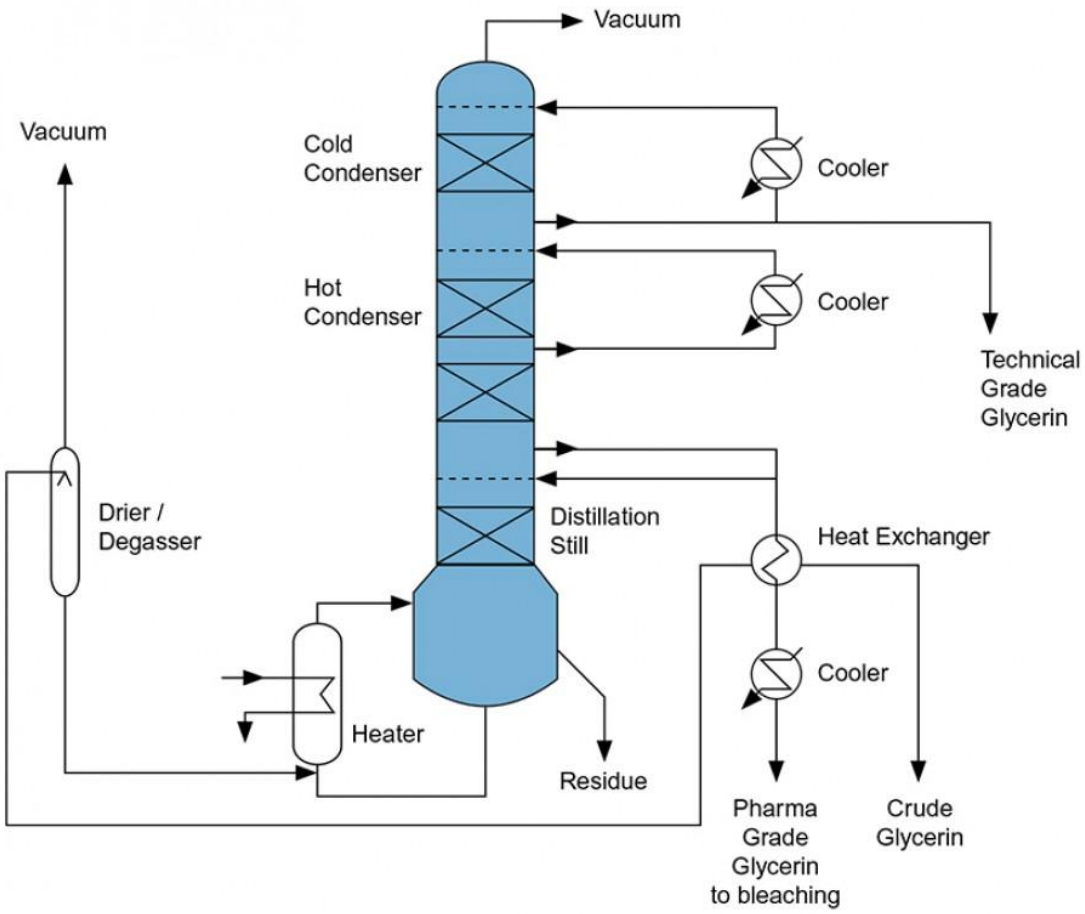


# Fatty Acid Composition

| Chain length | Palm Kernel Oil | Palm Oil | Palm Stearine | Palm Olein |
|---|---|---|---|---|
| C6 | 0.5 | - | - | - |
| C8 | 4.5 | - | - | - |
| C10 | 3.5 | - | - | - |
| C12 | 48.5 | 0.1 | 0.3 | 0.3 |
| C14 | 15.5 | 1.0 | 1.5 | 1.0 |
| C16 | 8 | 44.0 | 62.4 | 40.2 |
| C18 | 2 | 4.4 | 5.0 | 4.4 |
| C18:1 | 15 | 40.1 | 24.9 | 42.8 |
| C18:2 | 2.5 | 10.4 | 5.9 | 11.3 |

*PKO values are based on MS80:1987*
*CPO, Palm Olein and Palm Stearine values are based figures from MPOB*

# Glycerine Refining



# Fatty Alcohol Process

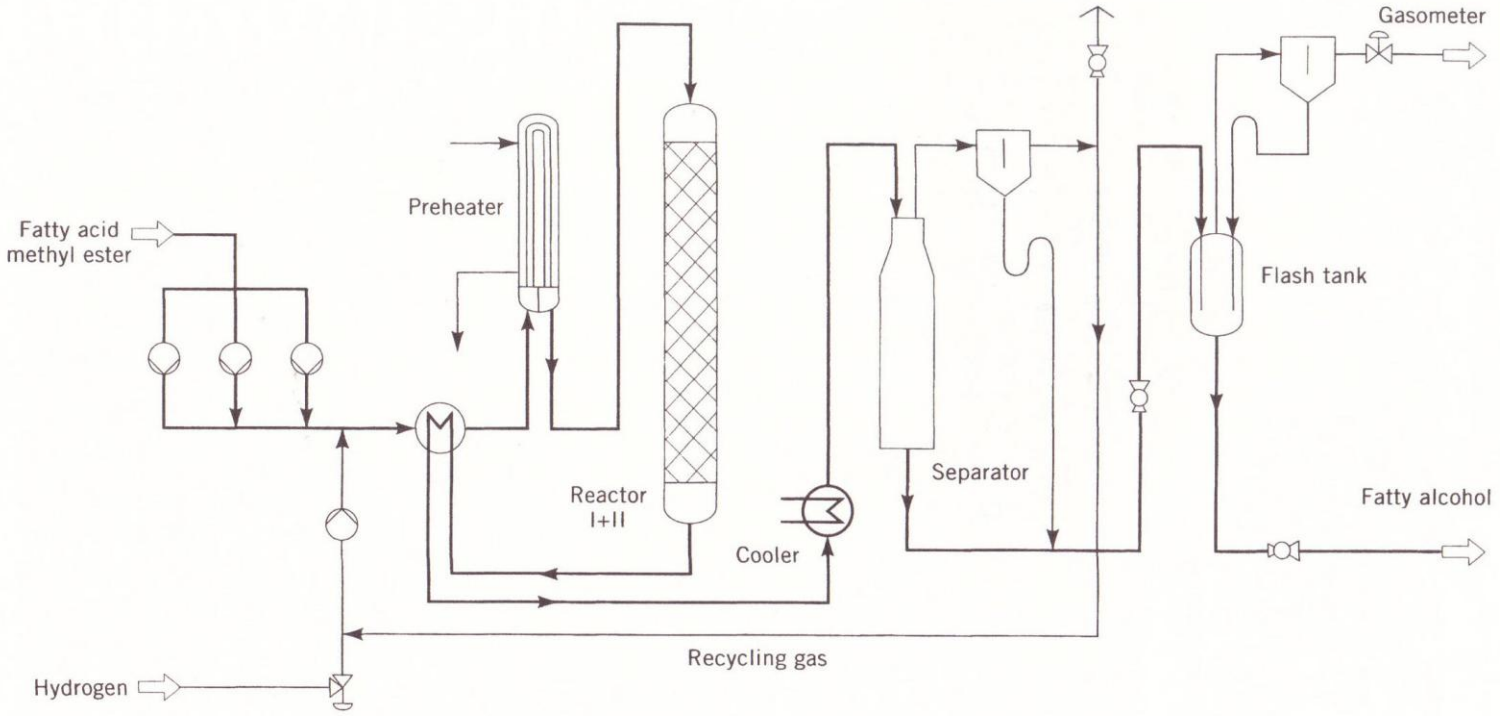
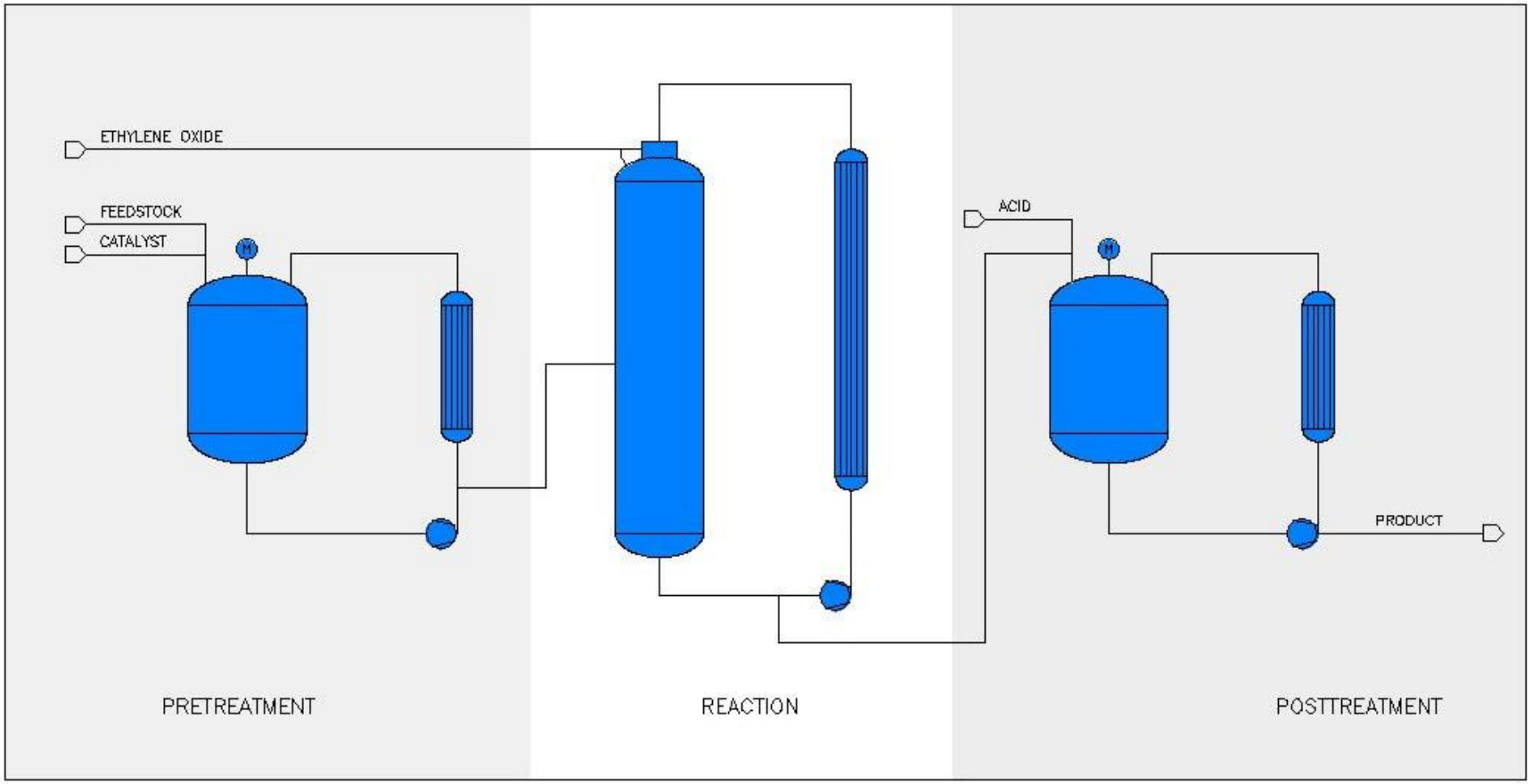


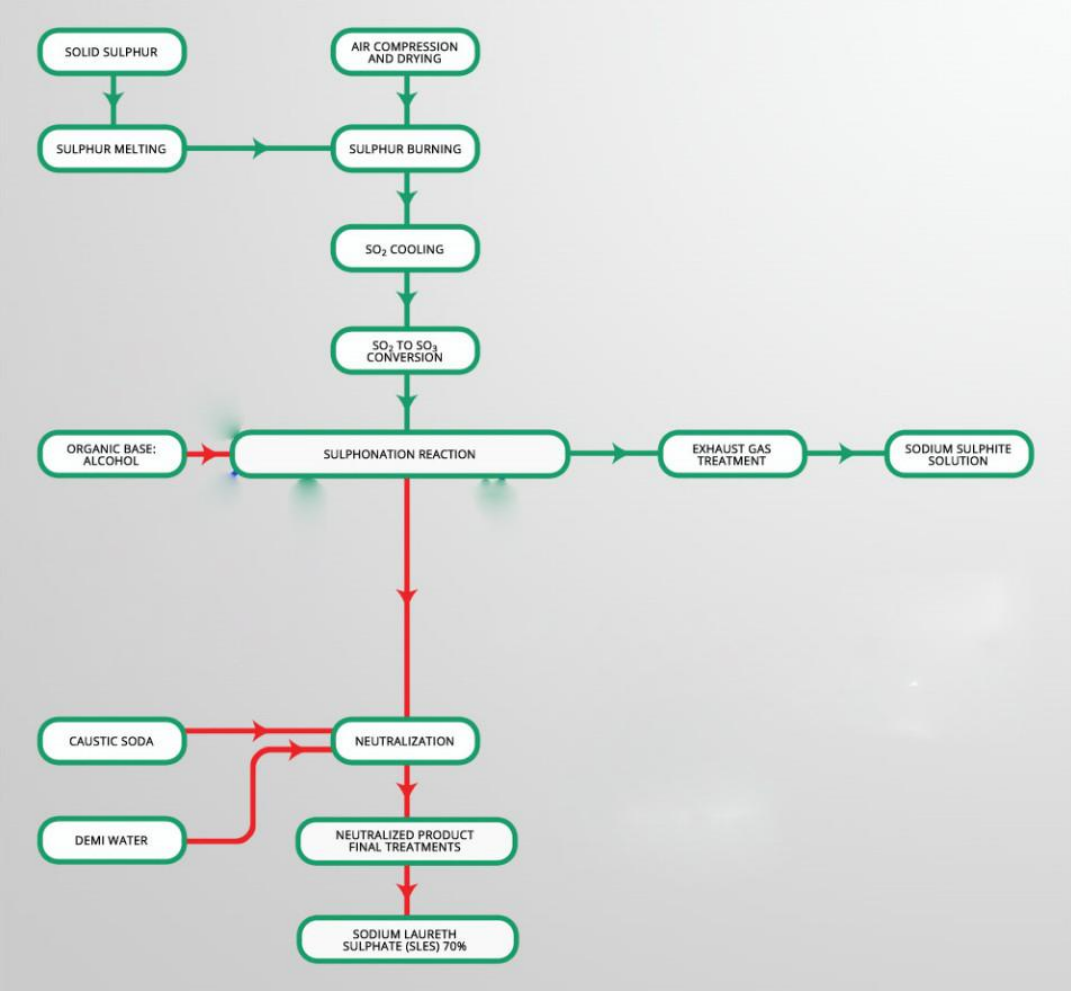

***Figure 11.*** *High-pressure hydrogenation of fatty acid methyl esters—fixed bed process (15).*

# Ethoxylation




Bubble ethylene oxide through the alcohol

# Sulphonation




Ethoxylated alcohol is treated with sulphur trioxide and then neutralized

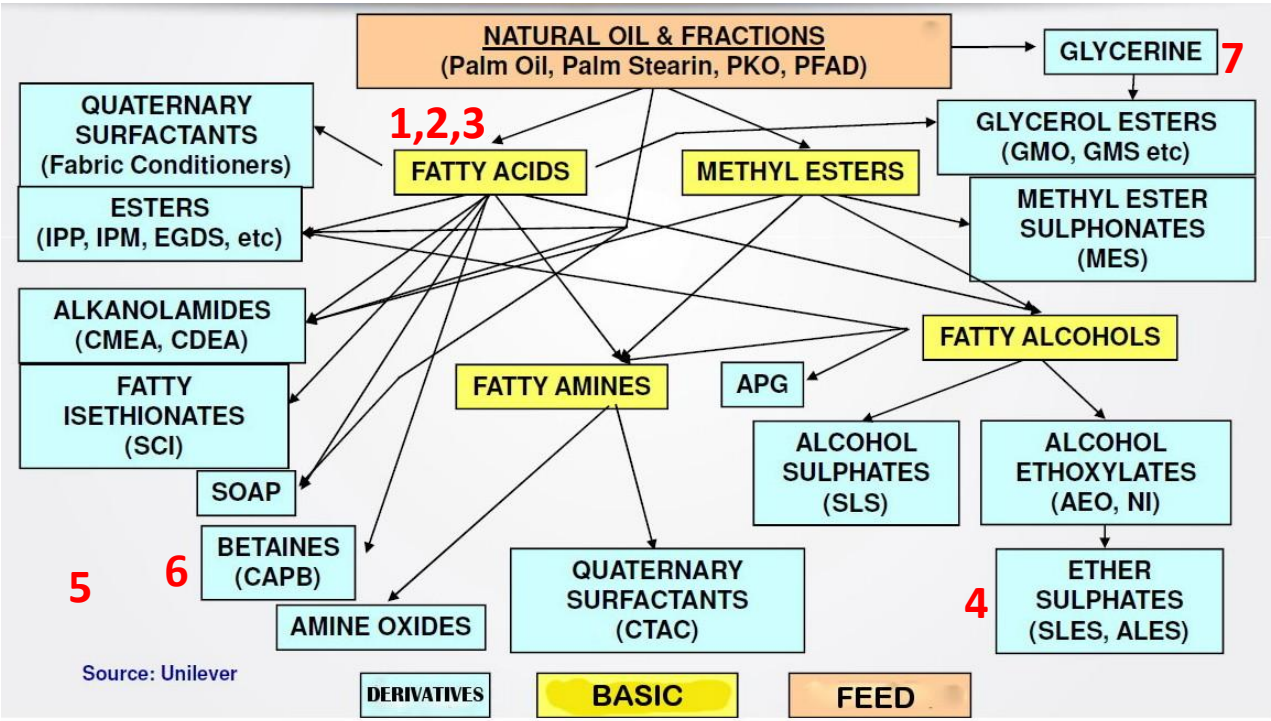
If starting ester is methyl laurate the product is sodium lauryl ether sulphate (SLES)

# Oleochemicals in your shower cream



| Nr | Oleochemical | Nr | Oleochemical |
|---|---|---|---|
| 1 | Myristic Acid | 5 | Glycol Distearate |
| 2 | Lauric Acid | 6 | Cocoamidopropyl Betaine |
| 3 | Palmitic Acid | 7 | Glycerin |
| 4 | Sodium Laureth Sulfate (SLES) | | |

# Place in the value chain

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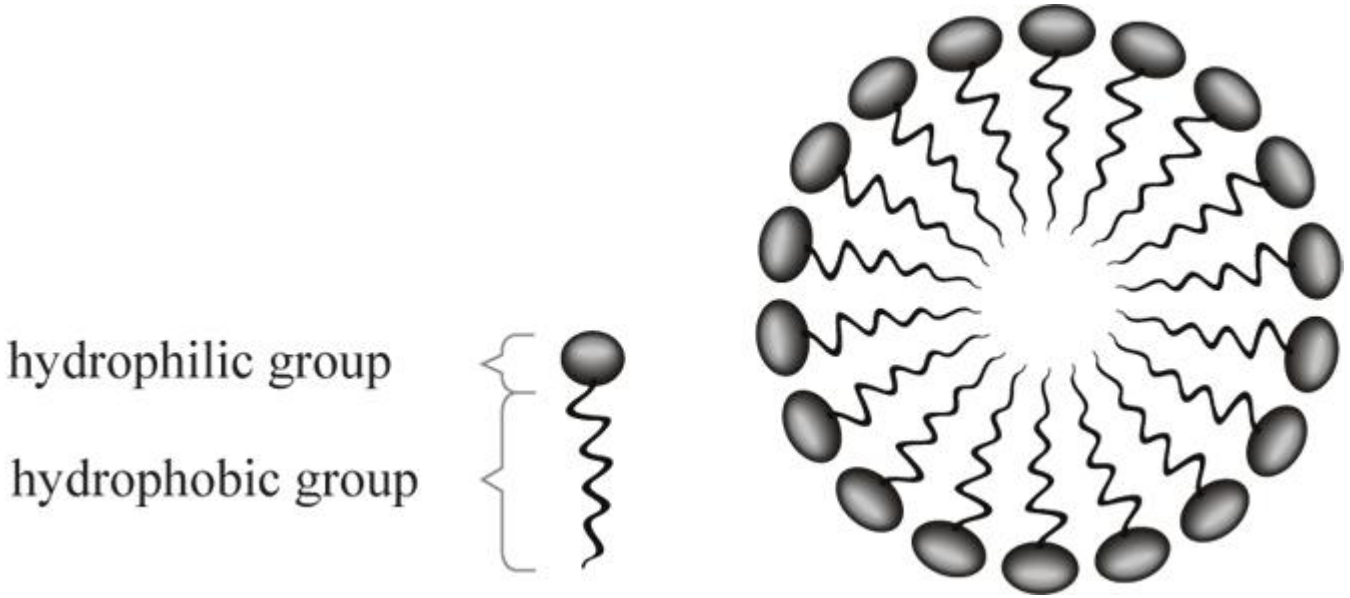
| 3 | Palmitic Acid | 7 | Glycerin |
| 4 | Sodium Laureth Sulfate (SLES) | | |

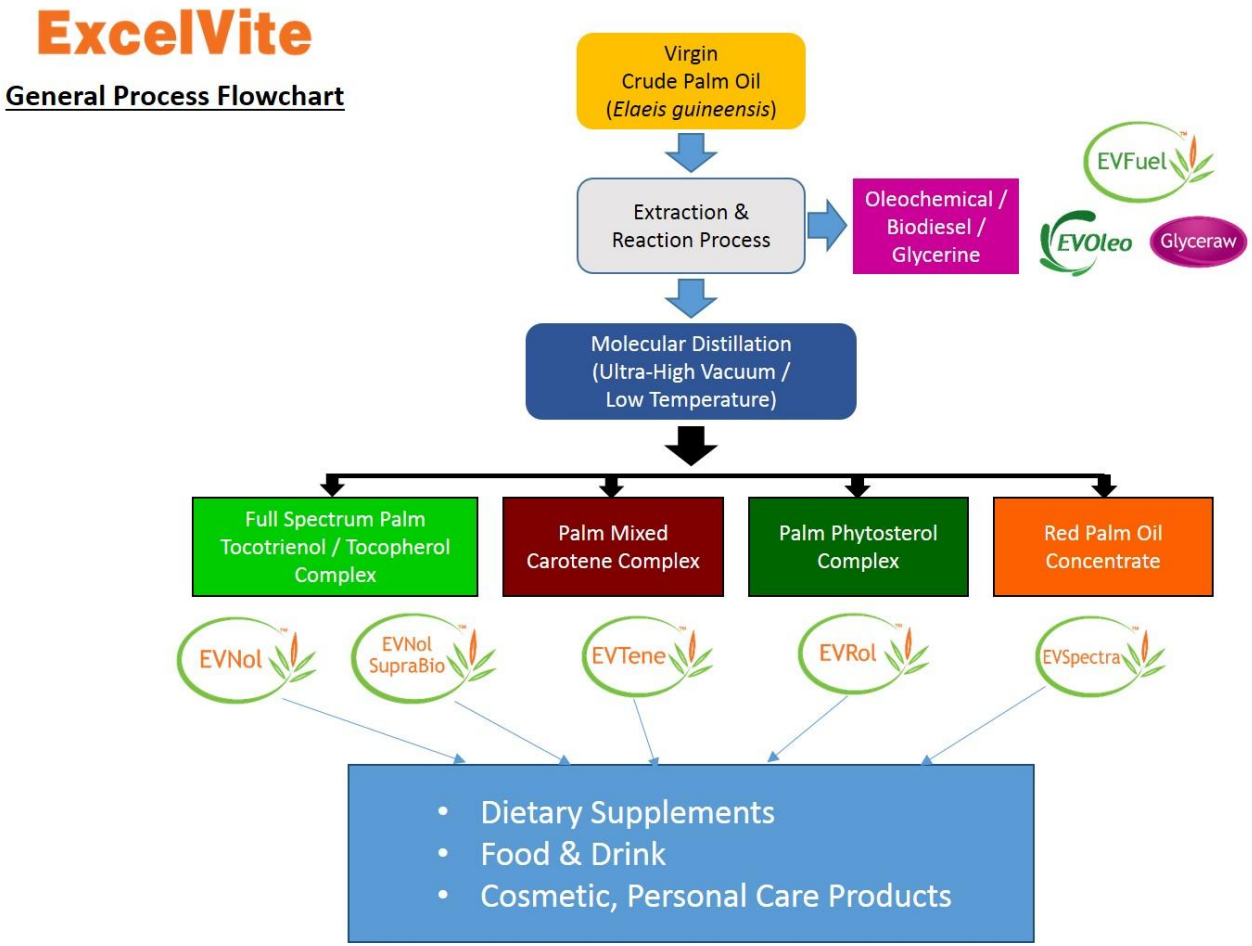
# Washing your hands

- Is antibacterial handwash better?
- Is there an ideal pH for soap?
- Do additives work?

# How does soap work



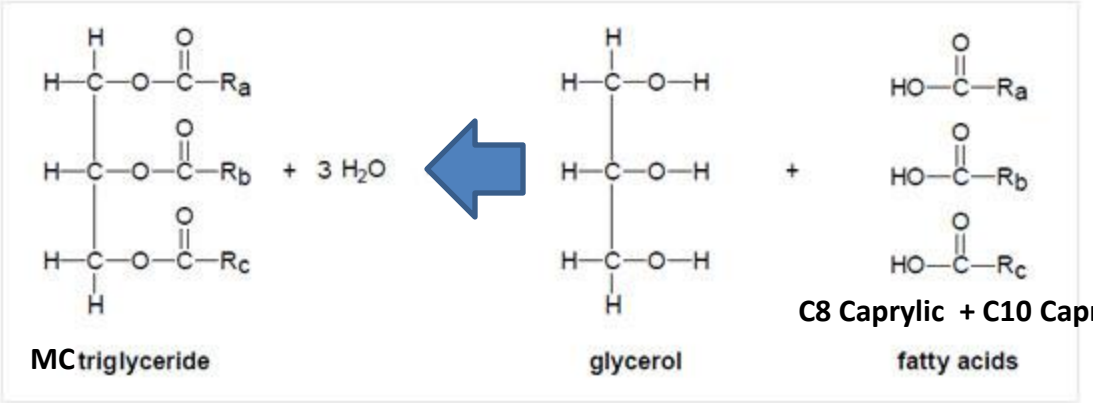
# Molecular Distillation to extract Phytonutrients



# End Consumer products …

| | | | | |
|---|---|---|---|---|
|  Soap noodles |  |  Sodium lauryl sulfate |  Stearic Acid |  Esters |
|  Glycerin, Isopropyl Myristate |  Methyl Ester Sulfonate |  Cetyl palmitate, isopropyl myristate, sorbitan monostearate, stearyl alcohol |  Amide as slip agent |  Tocotrienols |

# Medium Chain Triglyceride





# Bio-processes 1

Bioprocess engineering focuses on the role of living organisms in the manufacturing process

**Biodiesel**

- Enzymatic process can use feedstocks with low or high free fatty acids eg UCO and PFAD
- Eliminate hazardous catalyst eg sodium methoxide
- Lower energy

# Bio-processes 2

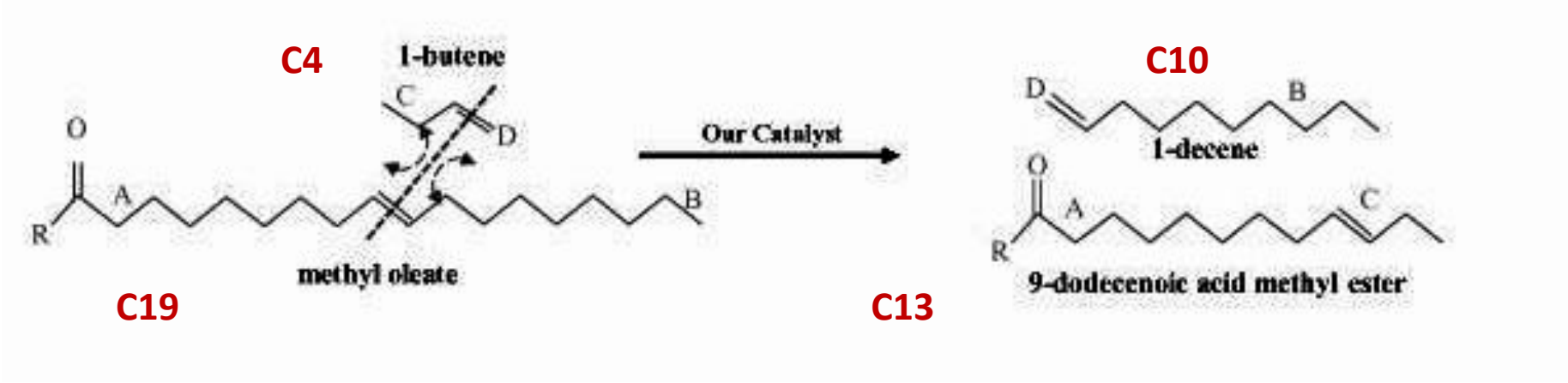
**Adipic Acid**

- Yeast fermentation to produce diacids
- Based on fatty acids (prev. petroleum)
- Low cost
- Less pollutants
- Key component of nylon 6,6

# What is a Biorefinery

- A facility that integrates biomass conversion processes and equipment to produce fuels, power, heat and value-added chemicals from biomass
- It is analogous to a petroleum refinery which produces multiple fuels and products from petroleum

# Elevance Metathesis Technology




- Metathesis can break carbon-carbon double bonds
- A petrochemical is combined with an oleochemical
- Molecules recombine into new di-functional molecules

# Three product streams

1. Olefins – 1-decene for co-polymers
2. Speciality chemicals – di-functional products from oleochemicals and petrochemicals in one molecule eg 9DDA (9-dodecenoic acid) are key products for nylon 6,12
3. Oleochemicals – C16 and C18 methyl esters eg for MES

# 4.Oleochemical Market

- ASEAN Oleochemical Manufacturers Group
- Volume and Value
- Prices and Margins
- Growth
- Challenges
- Likely outcomes

# AOMG members

## Indonesia

1. PT Ecogreen
2. PT Musim Mas
3. PT Nubika Jaya
4. PT Soci Mas
5. PT Unilever Oleochemical Indonesia

## Philippines

1. Chemrez

## Malaysia (MOMG)

1. Emery Oleochemicals
2. FPG Oleochemicals
3. Fatty Chemicals
4. IFFCO
5. IOI Oleochemicals
6. Natural Oleochemicals
7. Pacific Oleochemicals
8. Palm-Oleo
9. Southern Acids

(Previously Thai Oleochemicals now Global Green Chemical was a member)

Historically Western multinationals, Unilever, Henkel, Akzo, P&G, ICI and Croda were present

# AOMG activities

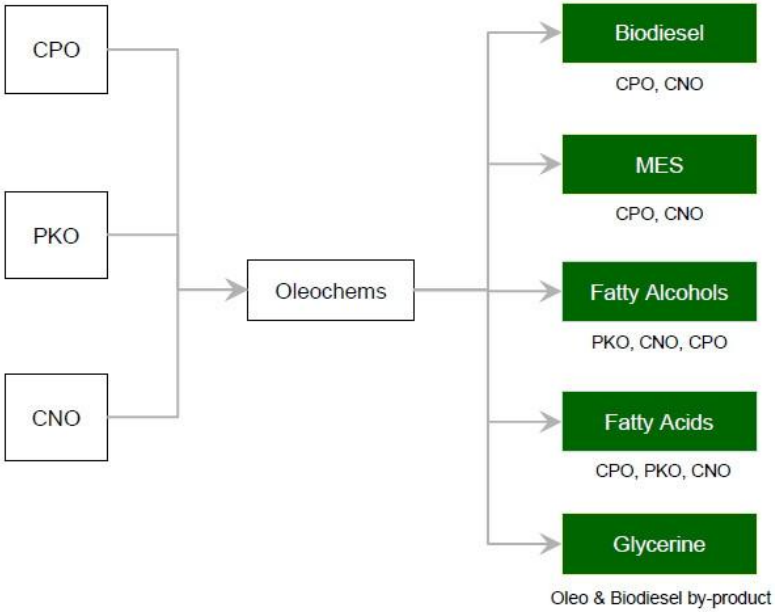
- Statistics
- Annual Process Safety Management workshop
- Safety Data Sheet
- RSPO

# ASEAN capacity

- 4 to 6 million tonnes
- Majority of palm based oleochemical capacity globally
- And growing

# Capacity growth is in Indonesia

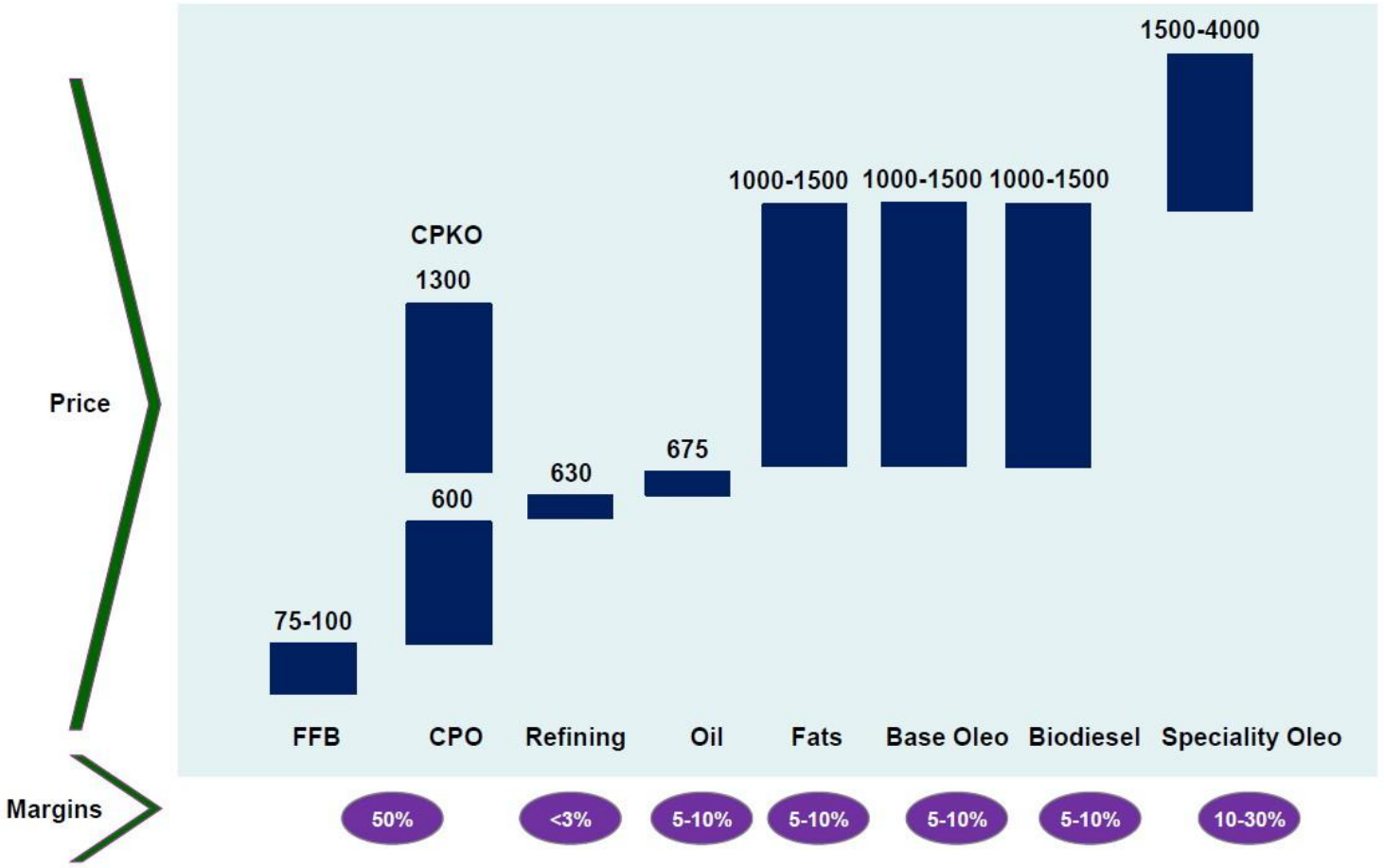
# Volume & value of oleochemicals
## (ca 70% PKO)




| | Volume 2015 (Mn MT) | Value 2015 (USD $ bn) | Projected CAGR ('15 to '20) | Margins |
|---|---|---|---|---|
| Biodiesel | ~32 | ~28 | 5-10% | 0-10% |
| MES | <300,000 MT | ~0.5 | 10% | 5-10% |
| Fatty Alcohols | ~3 | ~5 | 3-4% | 5-10% |
| Fatty Acids | ~8 | ~8 | 3-4% | 5-10% |
| Glycerine | ~3.5 | 1.8 | 5-10% | 5-10% |

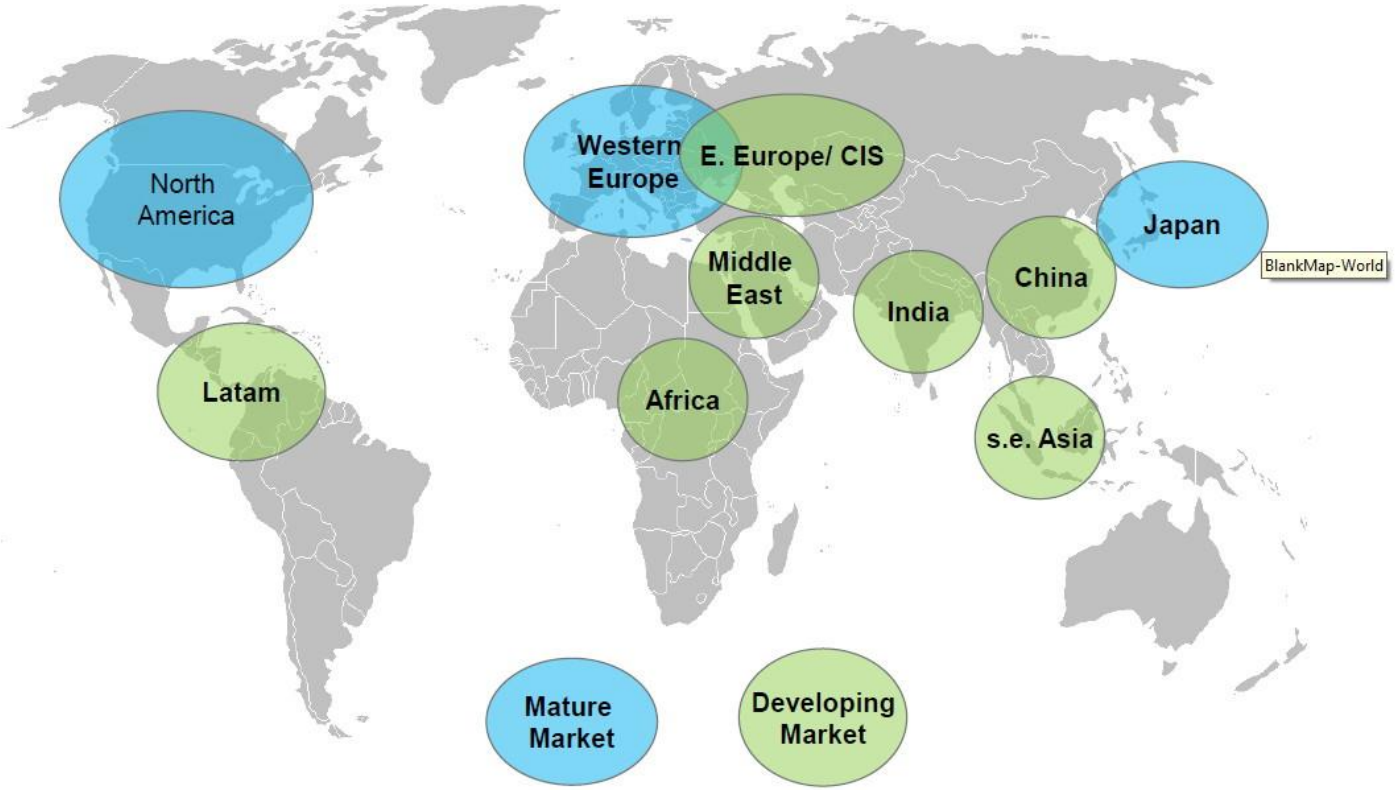
# Prices and Margins 2016

KPMG



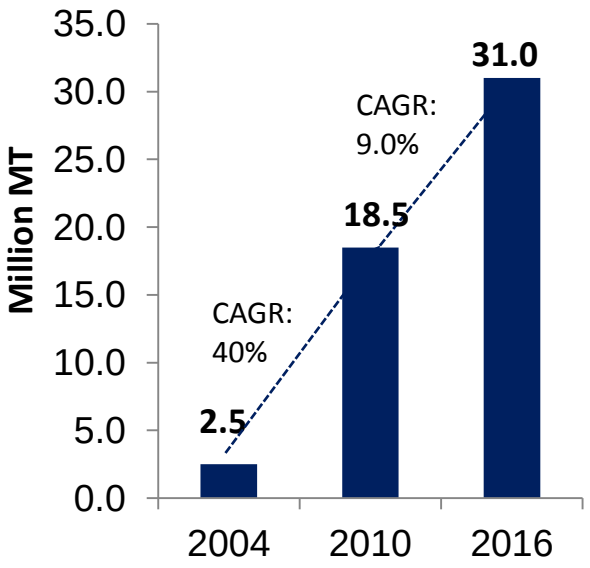
# Growth is in APAC

**APAC is 55-60% of production and 45-50% of consumption**



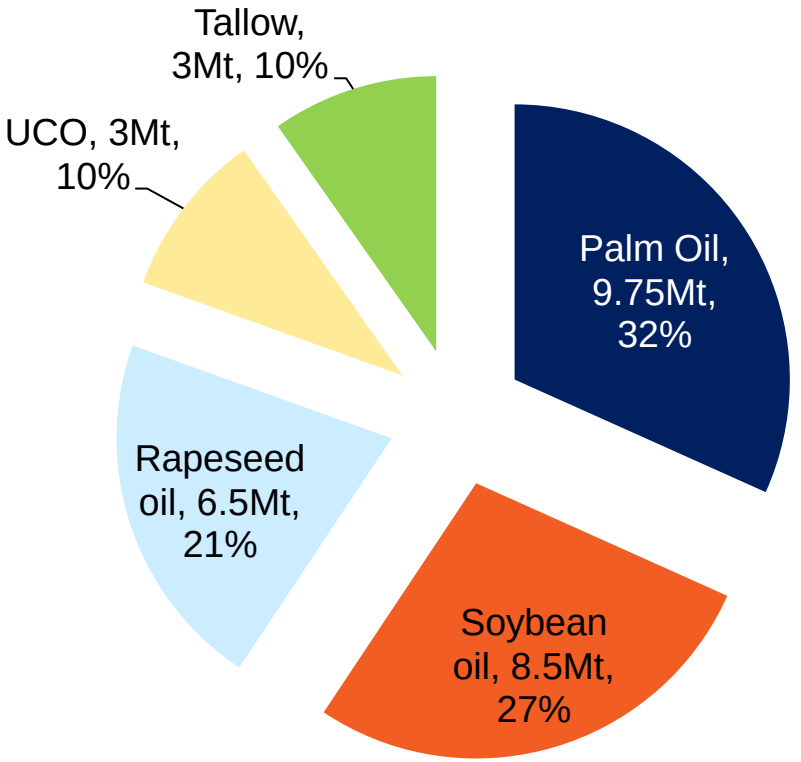
# Global Biodiesel Market

**Global Biodiesel Market**

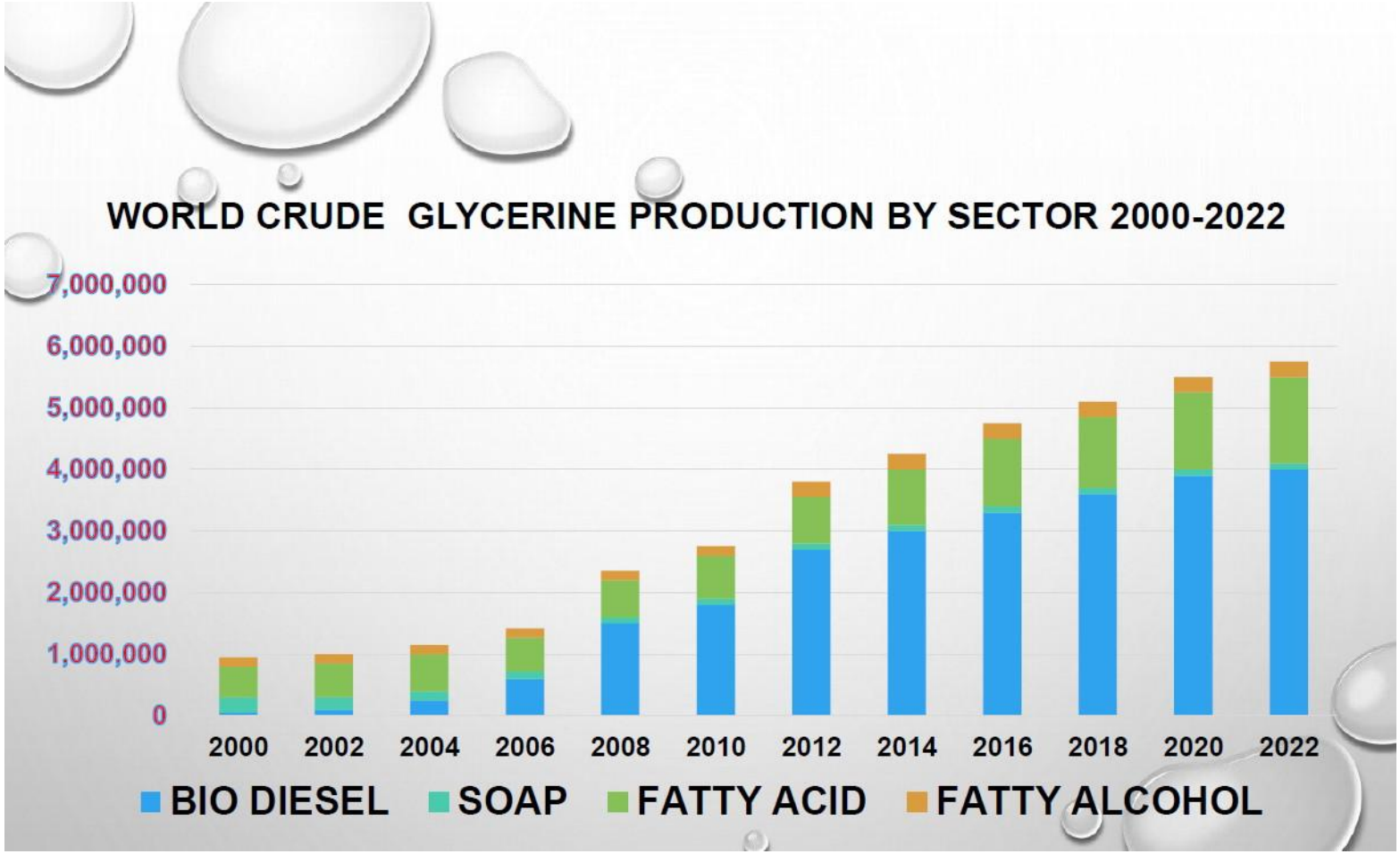



- **Market Size: 31 million mt, $ 25 billion.**

**Global Biodiesel Market by type of oil, 2016**

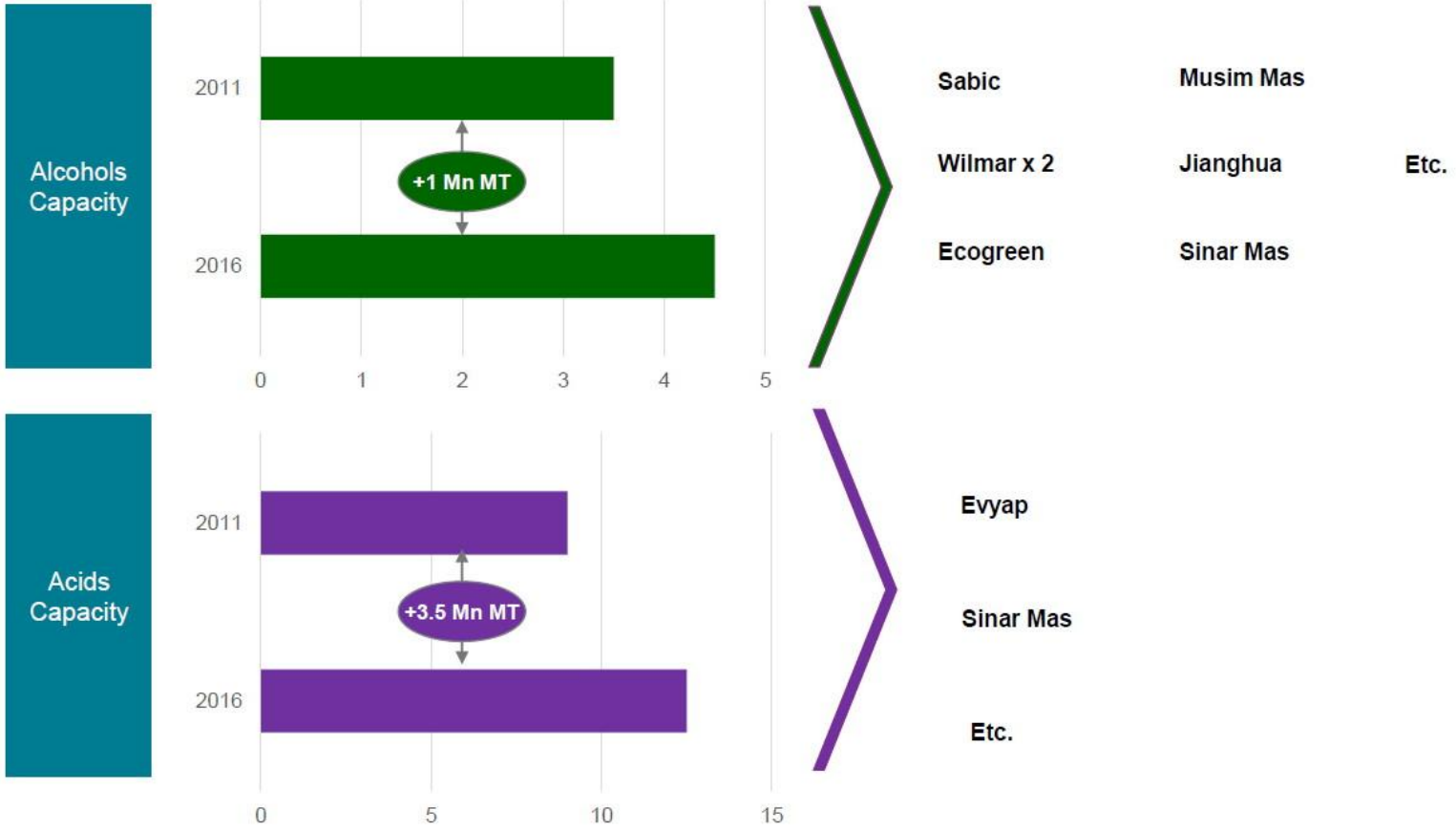


# World crude glycerine production



# The top 3 challenges

# Biggest issue - overcapacity



# Synthetic process for fatty alcohols

- Ethylene or natural gas feedstock

1. Ziegler process

$Al(C_2H_5)_3 + 18\ C_2H_4 \rightarrow Al(C_{14}H_{29})_3$ $Al(C_{14}H_{29})_3 + {}^3\!/_2\ O_2 + {}^3\!/_2\ H_2O \rightarrow 3\ HOC_{14}H_{29} + {}^1\!/_2\ Al_2O_3$

2. Oligomerized, hydroformylation, hydrogenation

$C_8H_{17}CH{=}CH_2 + H_2 + CO \rightarrow C_8H_{17}CH_2CH_2CHO$ $C_8H_{17}CH_2CH_2CHO + H_2 \rightarrow C_8H_{17}CH_2CH_2CH_2OH$

3. Shell higher olefin process

- No glycerine is produced

# Moving forward
# likely outcomes for oleochemicals

- More capacity to absorb vegetable oil supply
- Consolidation, weaker players drop out
- Synthetics on the rise, tough for alcohols
- Move toward specialities, margins erode?
- M&A and partnerships will increase
- Rise of biochemicals for margins & differentiation
- Innovation in feedstock, chemistry and processes
- Investment in infrastructure

# Conclusion

- Oleochemicals is versatile
- Appreciate fatty acids in our lives
- New processes are streaming in
- There is overcapacity
- Low crude oil prices impacts some sector
- The glycerine glut poses new opportunities

# Q&A

# Back up slides

# FAC of selected oils/fats

**TABLE 41. Fatty Acids Compositions of Selected Oils/Fats.**

| Fatty Acids | Weight Percentage | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Palm Oil | Palm Stearin | Tallow | Palm Kernel Oil | Palm Kernel Olein | Coconut | Palm Olein | Soybean Oil |
| C6 | — | — | — | 0.3 | 0.4 | 0.2 | — | — |
| C8 | — | — | — | 4.4 | 5.4 | 8.0 | — | — |
| C10 | — | — | — | 3.7 | 3.9 | 7.0 | — | — |
| C12 | 0.2 | 0.3 | — | 48.3 | 41.5 | 48.2 | 0.2 | — |
| C14 | 1.1 | 1.3 | 2.5 | 15.6 | 11.8 | 18.0 | 1.0 | — |
| C16 | 44.0 | 55.0 | 26.6 | 7.8 | 8.4 | 8.5 | 39.8 | 6.5 |
| C18 | 4.5 | 5.1 | 21.8 | 2.0 | 2.4 | 2.3 | 4.4 | 4.2 |
| C18:1 | 39.2 | 29.5 | 42.8 | 15.1 | 22.8 | 5.7 | 42.5 | 28.0 |
| C18:2 | 10.1 | 7.4 | 2.3 | 2.7 | 3.3 | 2.1 | 11.2 | 52.6 |
| Other | 0.8 | 0.7 | 4.0 | 0.1 | 0.1 | — | 0.9 | 8.0 |
| IV | 53.3 | 35.5 | 35–48 | 17.8 | 25.5 | 9.5 | 58.4 | 133 |
| SAP. V | 196 | 199 | 195 | 245 | — | 256 | 198 | 192 |

# Bodywash, shampoo, dog shampoo and soap

| Attributes | Bodywash | Shampoo | Dog shampoo | Soap |
|---|---|---|---|---|
| pH | 5 to 6.5 | 4 to 6 | 6.5 to 7.5 | 10 |
| Matter | Living skin | Hair is dead | | |
| Surfactant | Mild | More, hair is dirty | | |
| Foam | More | Less | | Poor in hard water |
| Residues | None | None | | Scum |
| Skin | 10-15 layers | | 3-5 cell layers | Damage hair |

Cat's skin pH in the range of 7.0 to 7.2. Cats don't usually need a bath. Make sure no tea tree oil or flea control products if you use dog shampoo.