FUTURE PROSPECTS FOR PALM OIL PROCESSING

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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.

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Refining Options

Crude Oil

Chemical Refining

Degumming

Neutralisation

Bleaching

Deodorisation

Physical Refining

Degumming

Bleaching

Steam refining-Deodorisation

GUMS

SOAPS

SPLITTING

FFA

Refined Oil

Refining Practices

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 catotene:

- 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

	Special quality (SQ) grade	Std quality I	Std quality II
FFA (% max)	2.5	3.5	5.0
M and I (% max)	0.25	0.25	0.25
PV (meq O_2/kg max)	2.0	-	-
AnV (max)	4.0	-	-
DOBI (min)	2.8	2.5	2.2

	Special grade	Lotox	Std
FFA (% max)	2.5	2.5	3.5
Carotene (ppm max)	-	600-700	-
Fe (ppm max)	4	4	5
Cu (ppm max)	0.02	0.2	0.2

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Quality Parameters

- 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.

DOBI = UV absorbance (446nm)/ UV absorbance at 269 nm

carotene — 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

Crude Palm Oil	Bad grade	Poor grade	Poor grade	Poor grade	Fair grade	Good grade
FFA (%)	7.21	4.32	3.54	4.91	2.79	1.90
DOBI	1.34	1.76	2.02	2.23	**2.67**	**3.13**
PV (meq O_2/kg)	2.33	3.79	3.15	3.54	0.36	1.03
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.

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Processing Duality

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

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Improved Deodorisation

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

Principle of Dual Temperature Deodorizer

1) Moderate temperature - long time (stage 1)

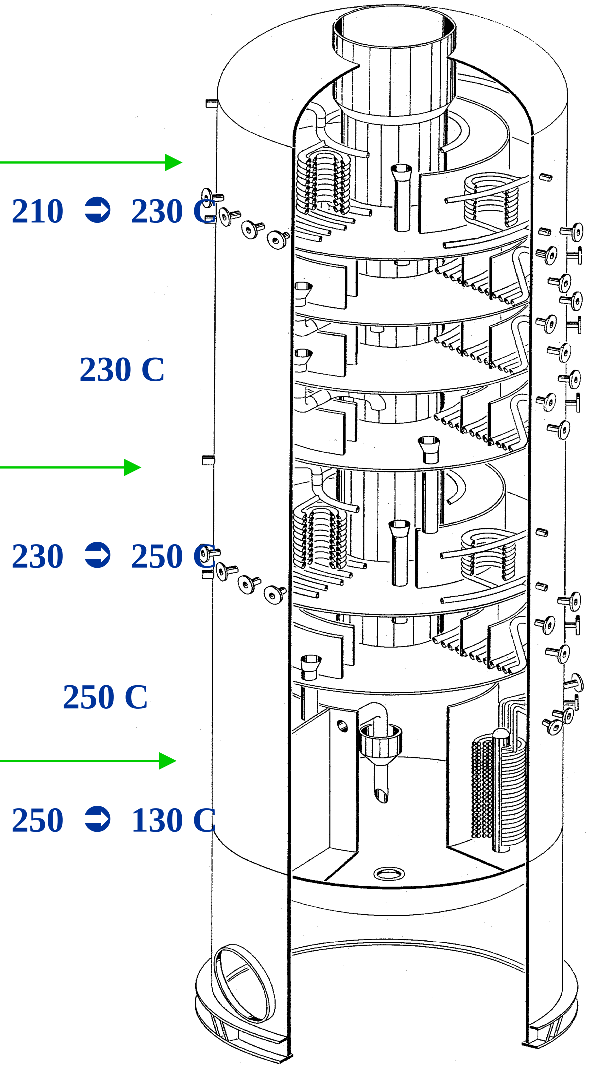
Mild deodorisation and moderate stripping

- deodorisation and deacidification -

2) High temperature - short time (stage 2)

Final stripping and heat bleaching

- controlled stripping of valuable minor components -



High/low or Low/high

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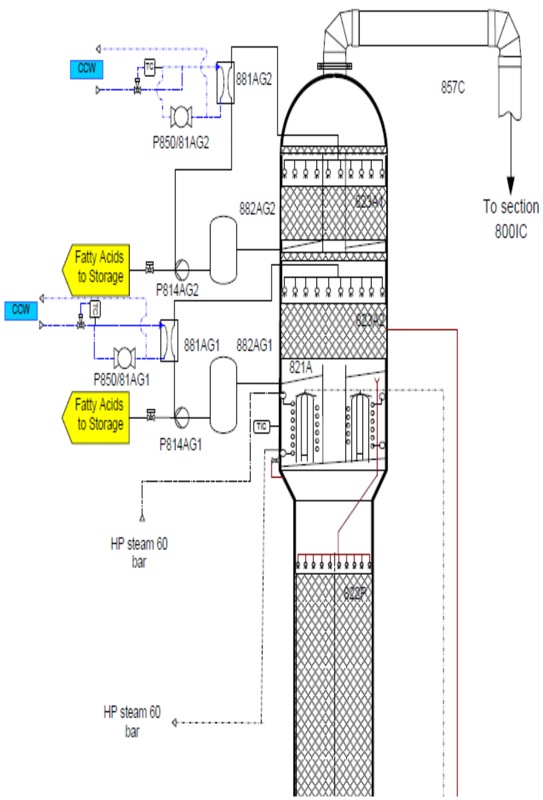
Improved Deodorisation

Recovery of valuable by-products

Double Condensing System

- Increases acidity of the fatty acid distillate
- Recovers valuable by-products



PFAD (fatty acid distillate)	Chemical Refining	Physical Refining		DCS
FFA (%)	33-50	**80-85**	**88.0**	**98.1**
Neutral oil (%)	25-33	5-10		
MAG (%)			2.0	**0.7**
DAG (%)			0.7	**0.05**
TAG (%)			8.0	**0.1**
Unsap. (%) (tocos, sterols …)	25-33	2-8	2.0	**<1**

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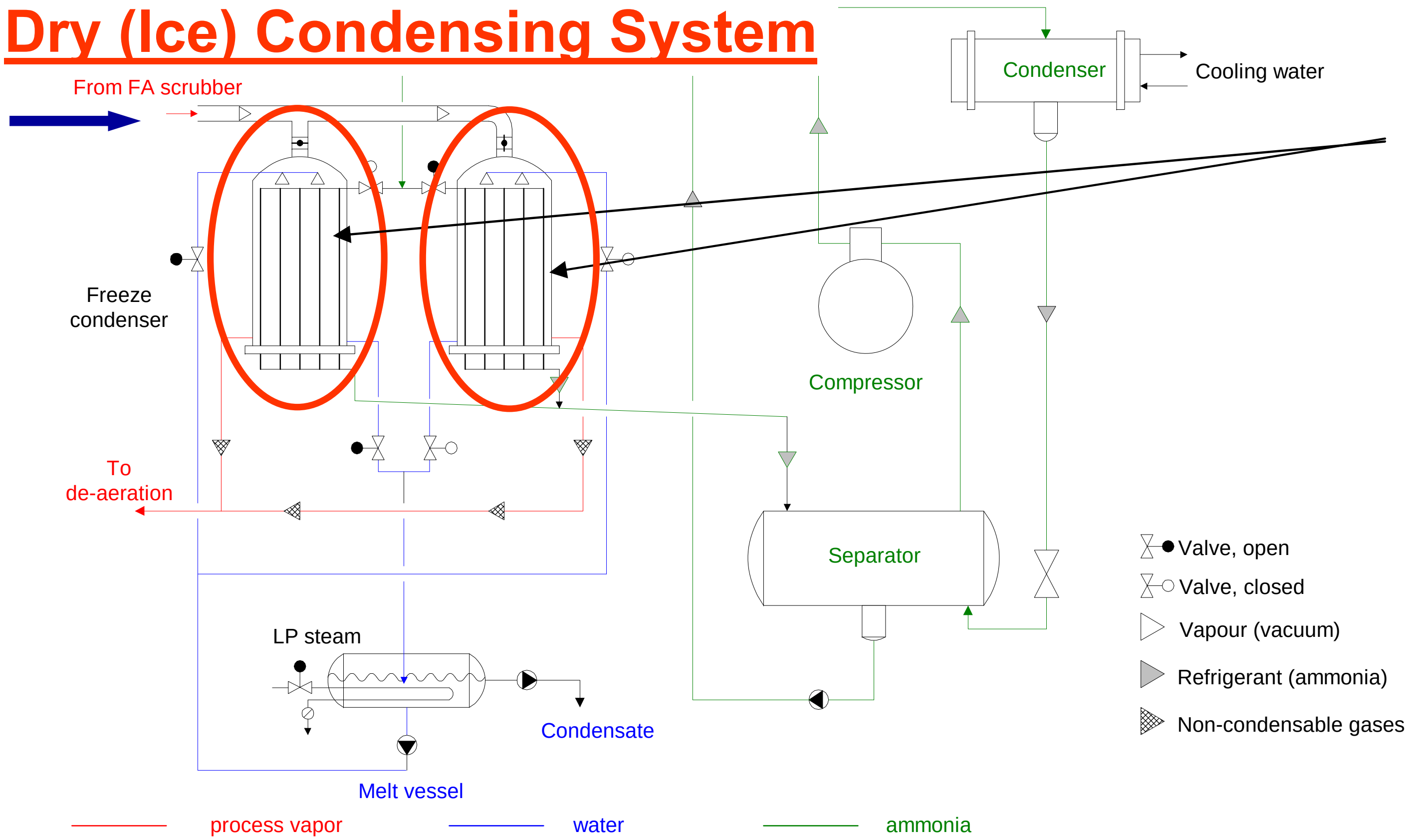
Improved Deodorisation

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

Dry (Ice) Condensing System



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)

	RBD Palm Oil Ref.	Golden Palm Oil A	Golden Palm Oil B	Golden Palm Oil C	Golden Palm Oil D
FFA (%)	0.07	0.20	0.07	0.08	0.07
Lovibond 5”1/4 (R/Y)	**2.5/25**	**11.6/70**	**6.2/50**	**4.8/50**	**4.1/42**
Tocos (ppm)	**545**	**709**	**671**	**630**	**699**
OSI (h at 97.8°C)	70.5	61.5	63.0	50.6	53.4

Specially Refined Palm Oil

High Vitaminic Palm Oil (chemically refined):

	Crude	Degum. and Neutr.	Degum., Neutr. and Deod.
FFA (%)	2.56	0.06	0.03
Phosphorus (ppm)	16	3	< 1
DOBI	3.1	-	-
Carotene (ppm)	580	579	**1.0**
Tocos (ppm)	733	679	**566**

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)	**227**
α- tocopherol	202
β- tocopherol	-
γ-tocopherol	25
Total tocotrienol (ppm)	**656**
α- tocotrienol	188
γ-tocotrienol	407
δ-tocotrienol	61

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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 Conditions 2 Conditions 3	0.9 0.7 **0.6**	3.6 2.8 **2.5**

Feedstock for Fractionated Products

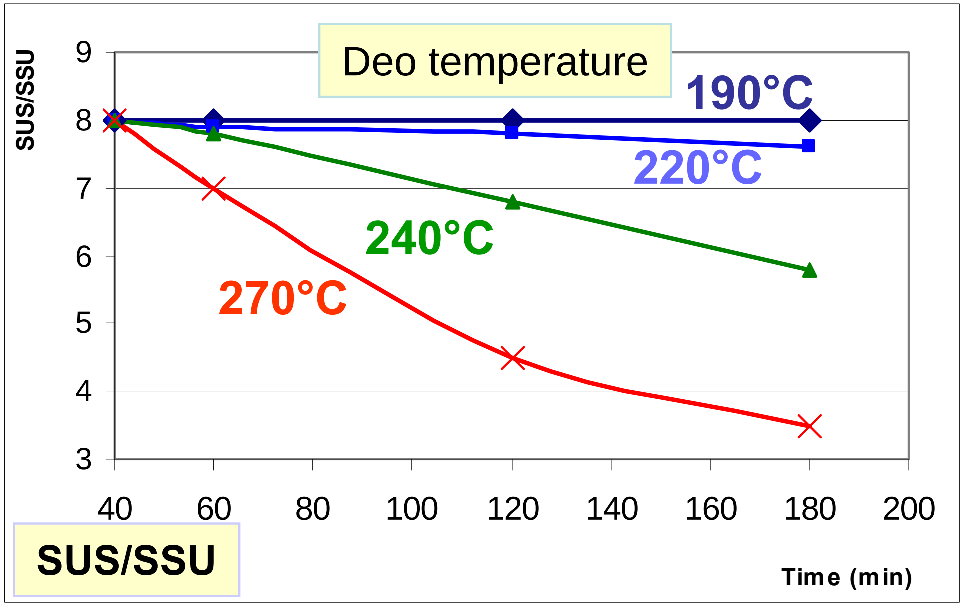
Specialty Fats

TAG composition not be affected

(optimal SUS/SSU: 8)

Optimized refining conditions

S: saturated; U: unsaturated FA



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Dry Fractionation Of Palm Oil

Palm oil

Food

↓

RB(D) PO
Commodity Fats, Special Products)

↓

Fractionation

↓

Oleins

Stearins

Nonfood

↓

FFA

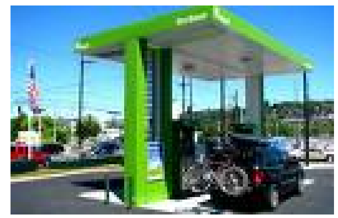
↓

Fractionation

↓

Oleic Acid

Stearic Acid



Biofuel

↓

FAME

↓

Fractionation

↓

Oleic FAME

Stearic FAME

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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

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Dry Fractionation Of Palm Oil

Membrane press filter developments

Any development in press filtration?

Bigger size → 25m3

Bigger plates → 2x2m

Higher pressure → 50 bar

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Dry Fractionation Of Palm Oil

Dynamic Concentric Crystallisers

Concentric Cooled Walls

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Dry Fractionation Of Palm Oil

Dynamic Tirtiaux Crystallisers

Cooling Fins

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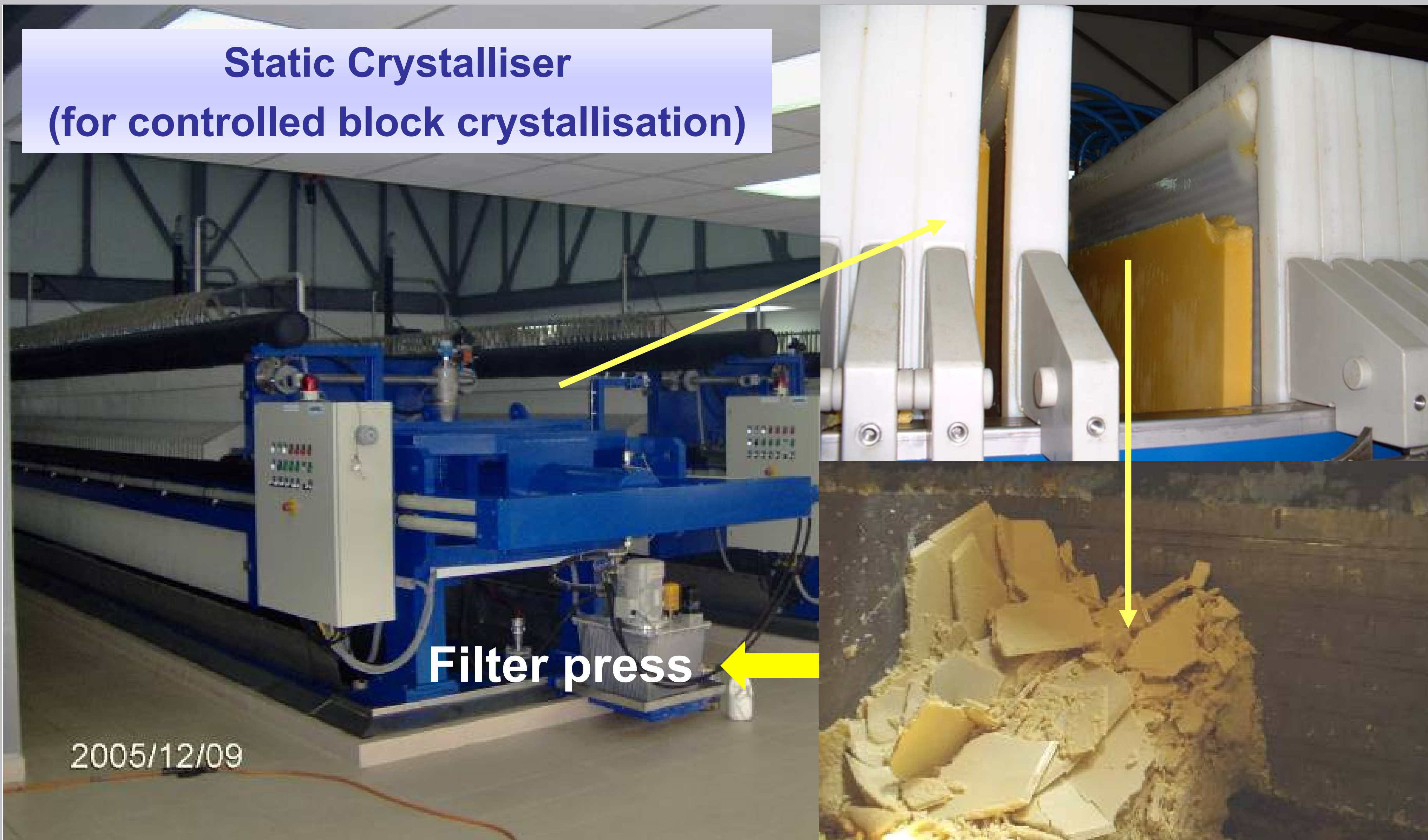
Dry Fractionation Of Palm Oil

Low Shear Crystalliser (special cooling surface configuration)

Near static crystallisation

Dry Fractionation Of Palm Oil



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Dry Fractionation Of Palm Oil
Multi-step Process

Heterogeneous TAG distribution → separation of compositionally distinct fractions

Commodity Fats

100% Palm Oil
IV 52

15% Palm Stearin
IV 36

Margarine

85% Palm Olein
IV 56

Frying Oil

Margarine

45% Soft PMF
IV 46

40% Super Olein
IV >64

Salad Oil

Specialty Fats

30% Mid Olein
IV 53

20% Mid Olein
IV 60

20% Top Olein
IV >67

Very cold stable salad oil

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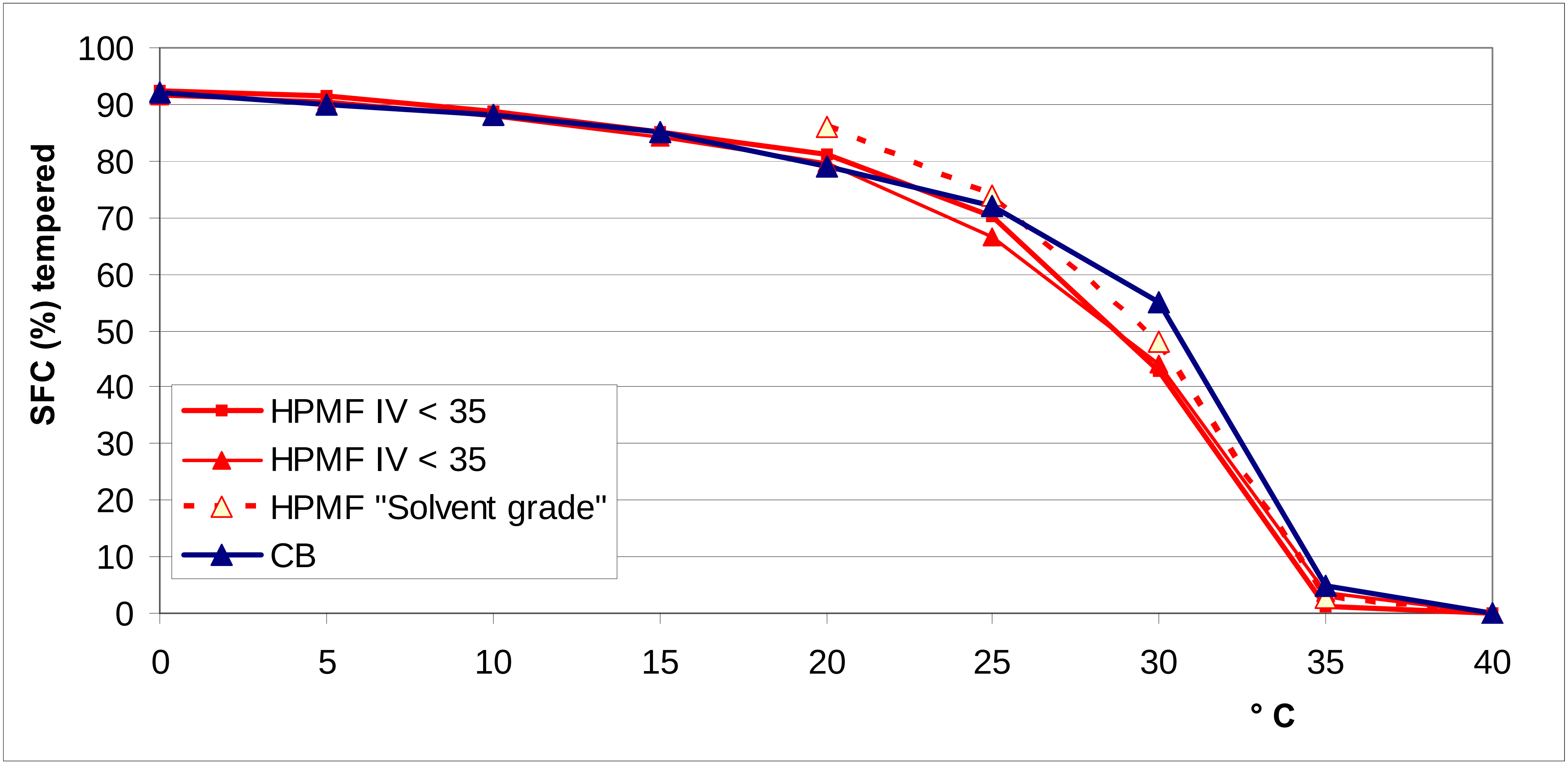
Special products: CBE
High POP Fractions

Signicative enrichment of POP in the Hard PMF

%	PO IV 52	POI IV56	SPMF IV 46	SPMF IV 45	HPMF IV < 35	HPMF IV < 35	CB
DAG	5.0	5.2	3.8	3.6	2.0	2.3	
PPP	5.2	0.4	0.2	0.8	0.9	2.0	
StOSt	0.3	0.2	1.1	0.9	1.3	1.1	26
POSt	5.0	5.0	9.3	8.5	11.0	12.1	37
POP	29.3	29.9	48.7	47.8	66.0	64.0	18

Special products: CBE
High POP Fractions

Solid fat content profile similar to Cocoa Butter



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Special products:
Red Palm Fractions

Golden Palm Oil
IV 51-53

⇩

Olein
IV 57-59

Salad Oils

⇩

Superolein
IV 64-66

⇩

Topolein
IV 70-72

Cold resistant and high vitatiminic liquid fractions

	IV	Cloud Point (°C)	Carotene (ppm)
Red Palm Oil	51.9	21.6	382
Red Olein	56.7	8.1	409
Red Superolein	63.2	3.3	670
Red Topolein	71.3	-2.4	854

Red solid fractions

Stearin
281 ppm
Carotene

⇨

Soft PMF
235 ppm
Carotene

⇨

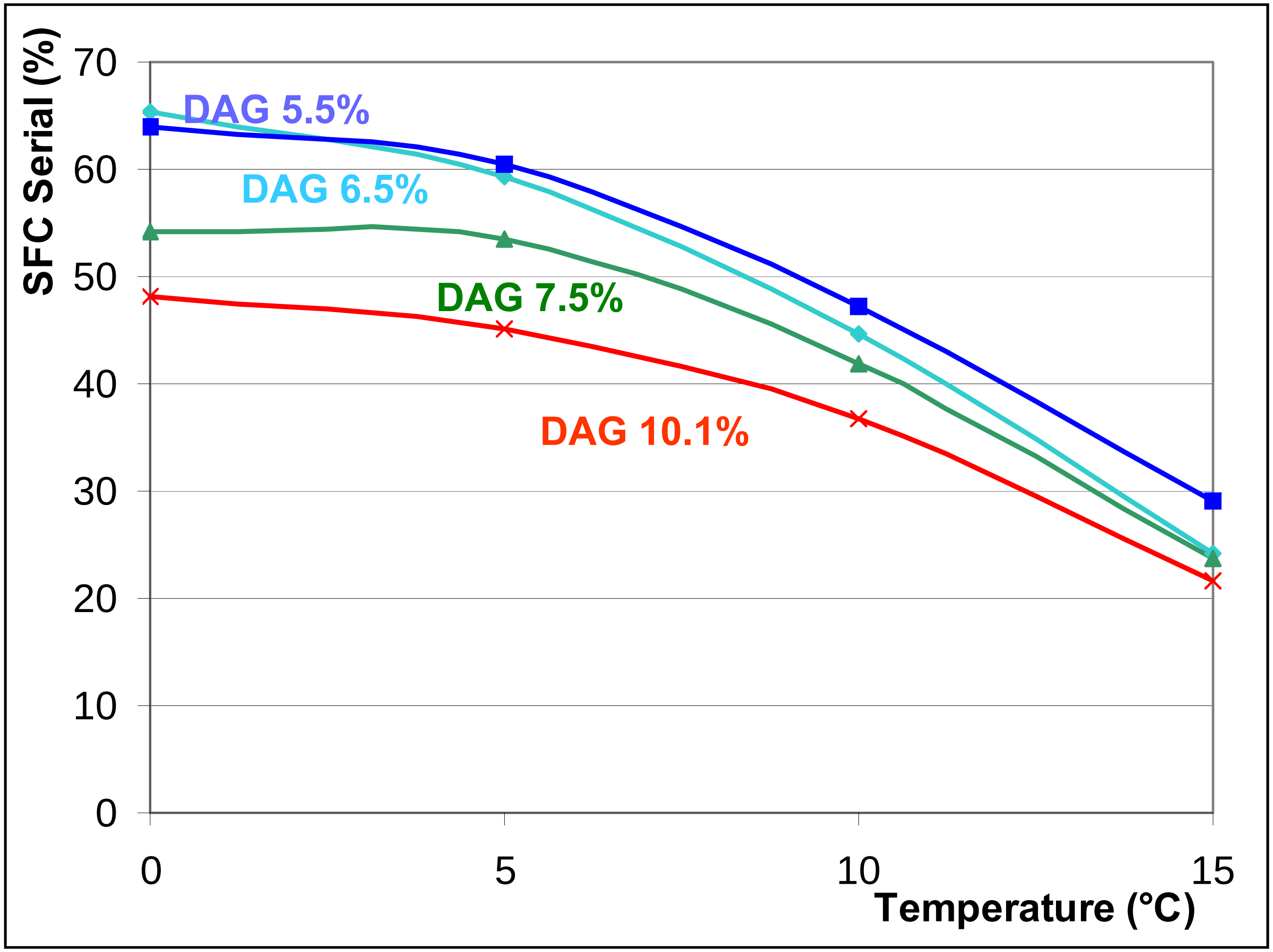
Hard PMF
80 ppm
Carotene

Influence of DAGs on Final Product Quality

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
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Cloud point increased
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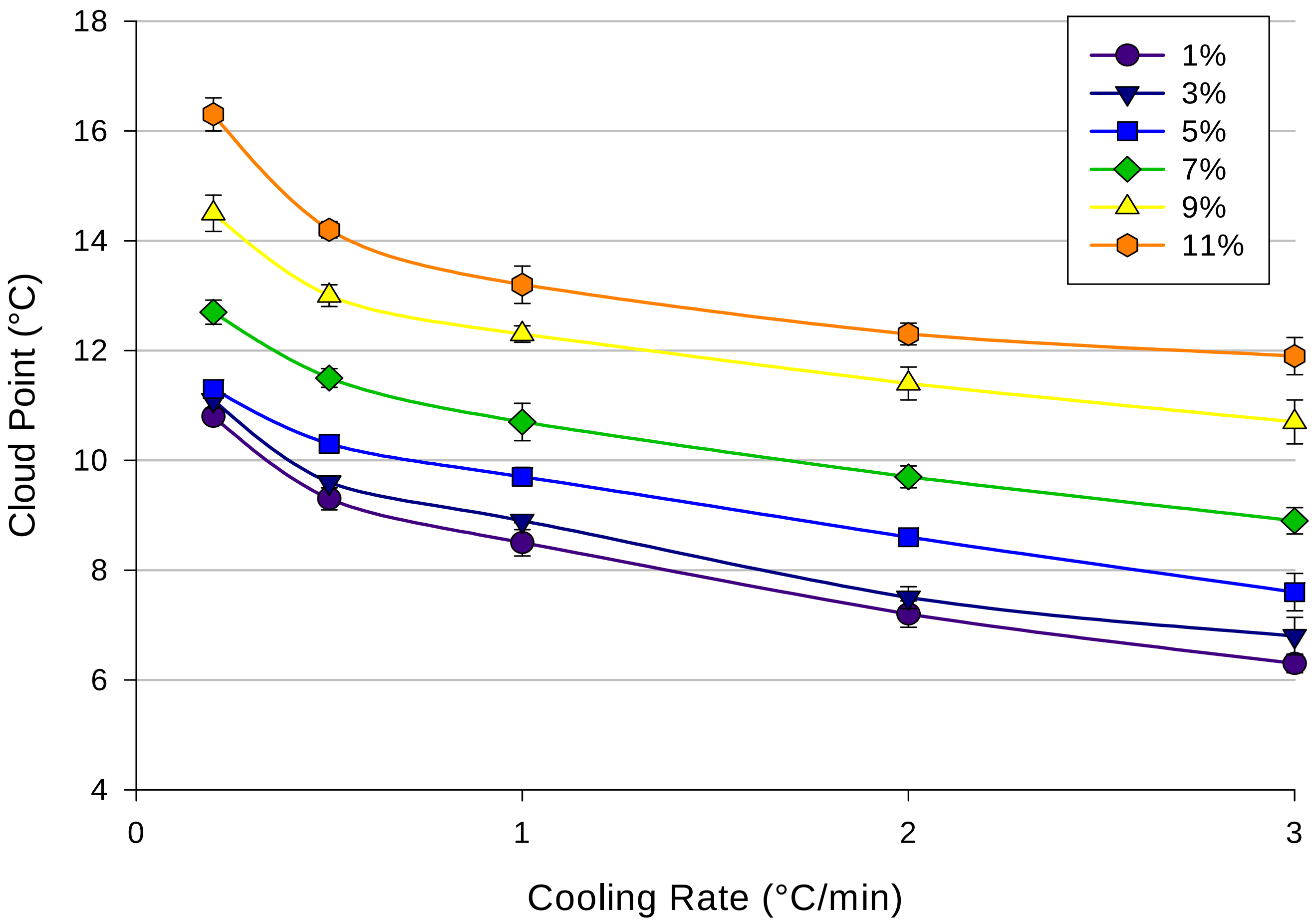

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Enzymatic Interesterification: "low trans" Commodity Fats

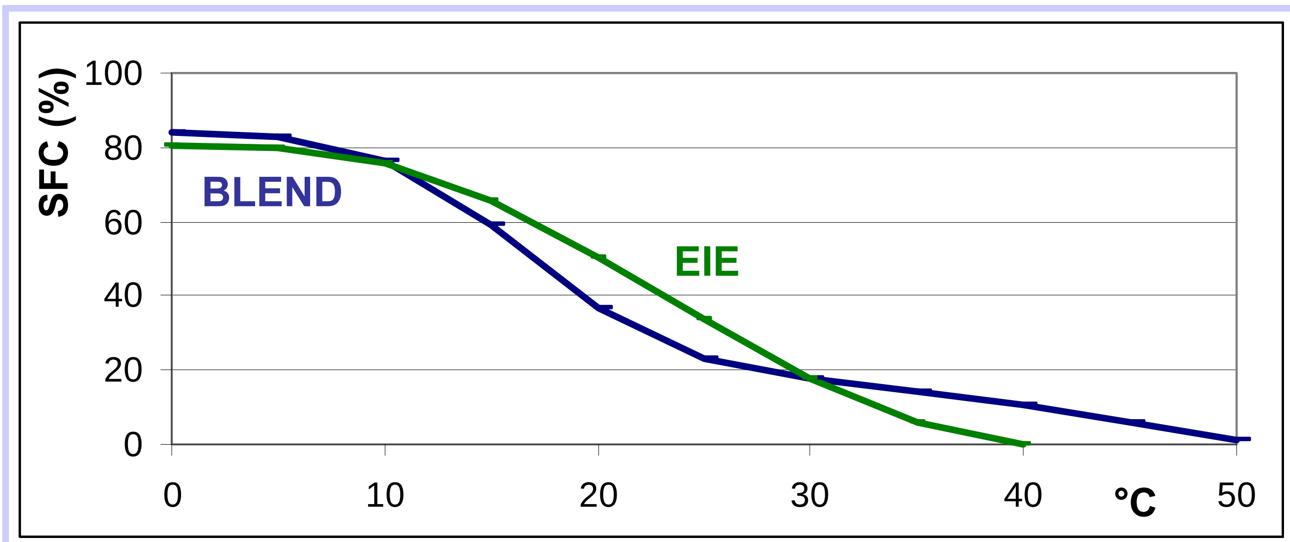
EIE = <u>RANDOM</u> re-distribution of FA on the glycerol:

→ improved oxidative stability (iso chemical interesterification)

ACA
BBB

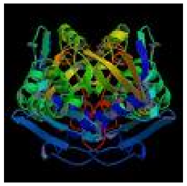
TL IM
(Novozymes)
nonspecific

AAA BBB CCC + ABA BBB BAC + AAB BBC ABA ACA + BBC BBA BAB BCB + CCA CCB CAC CBC



Enzymatic Interesterification: "low trans" Commodity Fats

- **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.**



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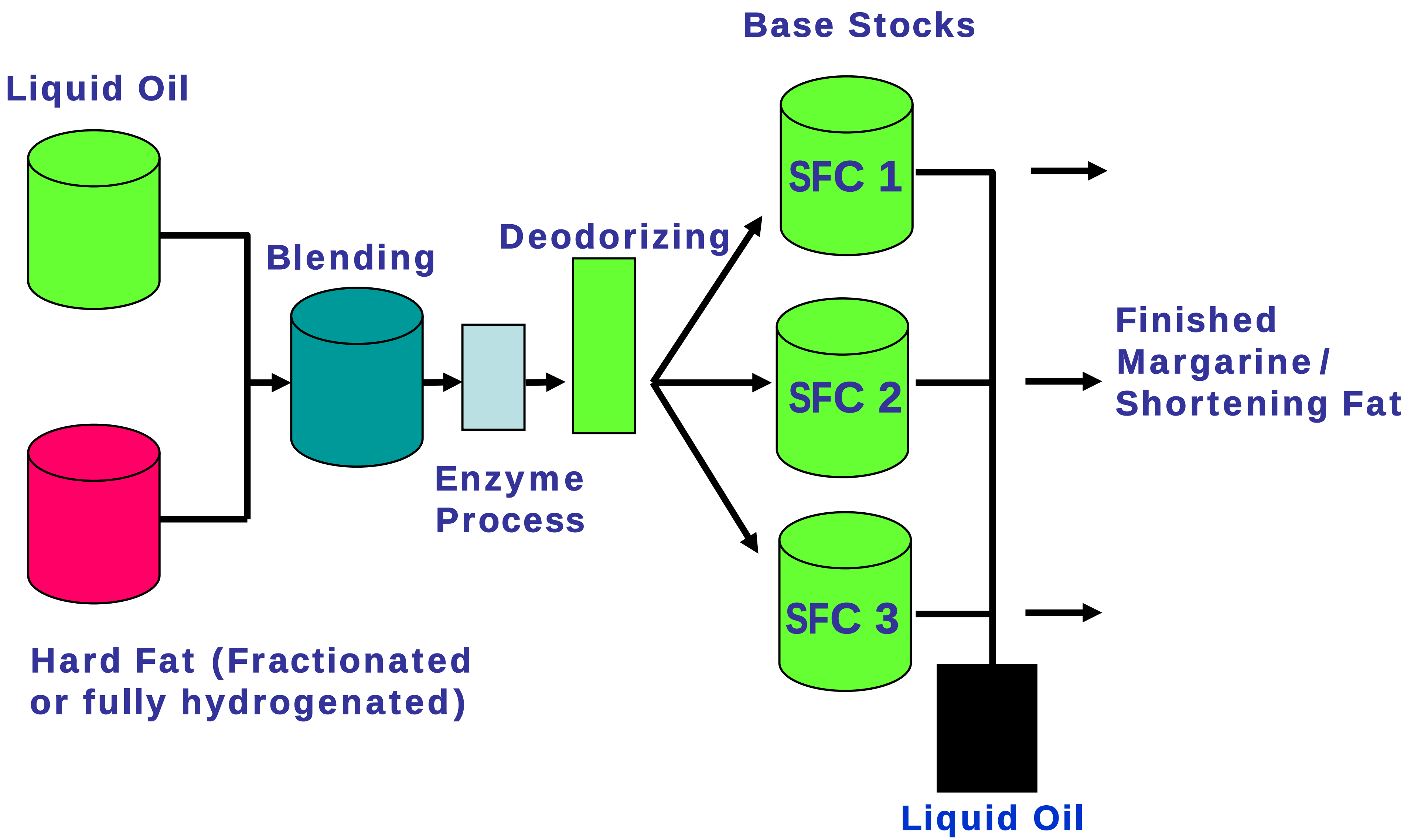
Enzymatic Interesterification: “low trans” Commodity Fats



Enzymatic Interesterification For Special Products

EIE = Regio-selective re-distribution of the FA on the glycerol:

→ sn 1,3 selective enzyme

A-C-A + B-B-B → RM IM (Novozymes) Sn 1-3 selective → A-C-A + B-B-B + A-C-B + A-B-A + B-B-A + B-C-B

- **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)

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EIE and Dry Fractionation for CBE Production

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

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EIE and Dry Fractionation for CBE Production

Soft PMF

Stripping /Dry Fractionation

CBE

%	SPMF
SSS	1.0
StOSt	1.6
POSt	9.0
POP	48.0

Specific EIE

%	EIE
SSS	8.0
StOSt	15.0
POSt	33.0
POP	15.0

%	FRAC$_1$
SSS	0
StOSt	16.0
POSt	36.0
POP	16.0

%	FRAC$_2$
SSS	0
StOSt	20.0
POSt	43.0
POP	20.0

+ "S" FFA/FAME

%	EIE
SSS	32.1
StOSt	21.0
POSt	22.0
POP	7.0

%	FRAC$_1$
SSS	0
StOSt	28.0
POSt	28.0
POP	10.0

%	FRAC$_2$
SSS	0
StOSt	35.0
POSt	34.0
POP	13.0

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Enzymatic Interesterification Plant

Lab reactor

Industrial plant

Pilot unit

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

Tank you very much for your attention