3-MCPD and GE mitigation in palm oil processing

– Webinar 7 May 2020

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Agenda

- A short introduction to Alfa Laval’s edible oil portfolio
- Edible oil industry trends and focus
- Introduction to the 3-MCPD and GE issues
- 3-MCPD mitigation in more depth
- Process routes to GE mitigation
- Conclusion

Our edible oil process line portfolio

– Comprehensive solutions

Crush and extract

Crude palm oil
Olive oil
Avocado oil

Clarify and water degum

Seed oil clarification
Water degumming (lecithin drying)

Degum/ neutralize/ dewax

Neutralization
Degumming (acid/enzymatic)
Dewaxing
Soapstock splitting

Bleach

Bleaching (absorption) to remove impurities

Deodorize

Deodorization (continuous or semi-continuous) to remove volatile components and thermally stabilize/bleach the oil

Modify

Modify by fractionation, interesterification or hydrogenation to produce liquid oils and fats with specific melting behaviours

Biodiesel/HVO feedstock

Cooking oils

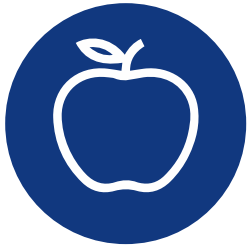
Margarine and shortening

Specialty fats end product

Industry trends

Industry trends and focus

– Shaping the future of margarine and shortening



Population growth

Significant rise in vegan and vegetarian population

Footprint in Asia, Africa and Europe

Increase in demand for plant-based food products

Industrial margarine market

More affordable, raw plant-based materials

Increased use of plant-based margarines

Demand for low-fat bakery and confectionery products

Health and wellness

More health-conscious consumers

More low-fat, low-calorie and trans fat-free products

More affordable, raw plant-based materials

Environmental footprint

Focus on image, legislation and utility cost

Water and energy savings

Continued investments in plant infrastructure

Introduction to 3-MCPD and GE issues

What are 3-MCPDE and GE?

- 3-monochloropropane diol (3-MCPD)
- 3-monochloropropane diol ester (3-MCPDE)

- Glycidyl ester (GE)

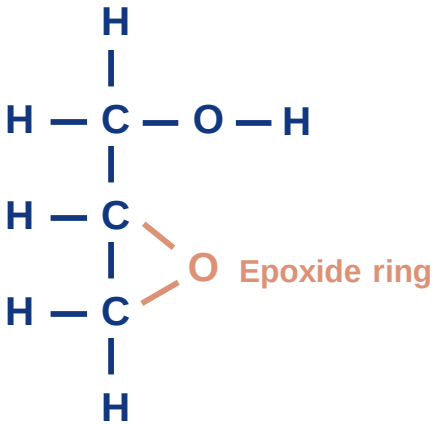
Why limit 3-MCPDE and GE exposure?

Classified as process contaminants

• 3-monochloropropane diol (3-MCPD)	Possibly carcinogenic to humans[1]
• 3-monochloropropane diol ester (3-MCPDE)	Harmful to kidneys (EFSA[2] report 2016)
• Glycidyl ester (GE)	Probably carcinogenic to humans[1]

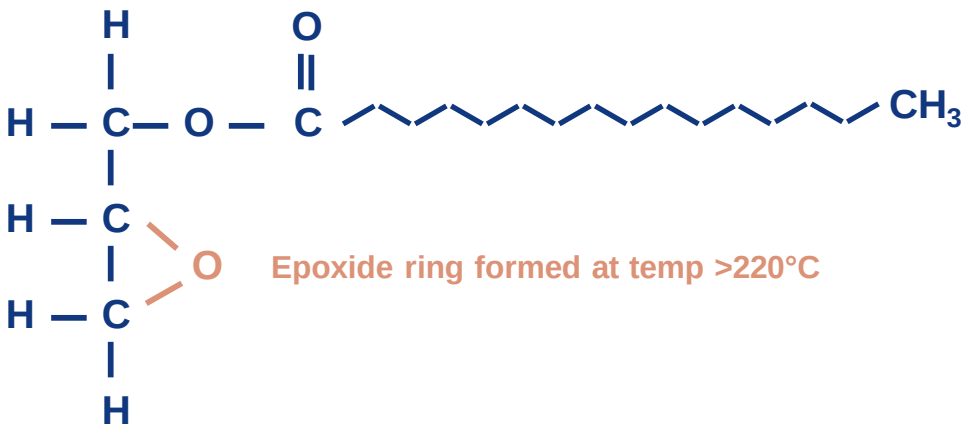
[1] Classification by International Agency for Research on Cancer
[2] European Food Safety Authority

Glycidol and glycidyl ester



Glycidol

Glycerol backbone **1 bonded fatty acid**



Glycidyl ester (GE)

3-MCPDE and GE have been around for decades

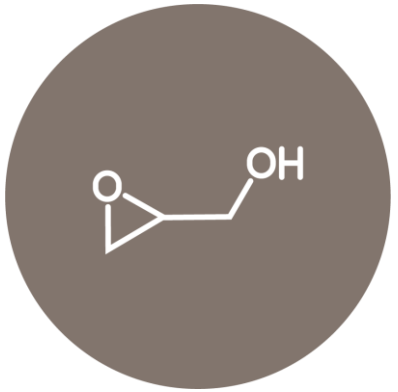
– But have gained more attention in recent years

1978	Known food contaminant in hydrolyzed vegetable proteins (HVP) and found in a wide range of daily food
2008	Glycidyl esters (GE) detected in palm oil but 3-MCPDs and GEs not found in virgin oils
2013	European Food Safety Authority (EFSA) identifies margarine, preserved meats, bread and vegetable oil as major sources of 3-MCPD
Jan 2018	EFSA sets the tolerable daily intake for 3-MCPDs at 2 µg/kg body weight/day (0.002 ppm/kg body weight)
2020 and beyond	Variable, but definitely at a ***very low rate***

Reactions of glycidyl esters

Glycidyl esters

Lipases + water



Glycidol + fatty acids

GEs are rapidly digested by gut lipases to form glycidol. Consequently, GEs should be considered as sources of glycidol exposure.[1]

[1] Food Addit Contam Part A Chem Analytical Control Expo Risk Assess. 2013;30(1):69–79. Epub 2012 Oct 22, “Application of gastrointestinal modelling to the study of the digestion and transformation of dietary glycidyl esters”, Frank N1, Dubois M, Scholz G, Seefelder W, Chuat JY, Schilter B.

EU legislation on GE affects supply chain

Glycidyl fatty acid esters expressed as glycidol	Maximum level µg/kg
Vegetable oils and fats placed on the market for the final consumer or for use as an ingredient in food with the exception of the foods below	1,000 **1.0 ppm**
Vegetable oils and fats destined for the production of baby food and processed cereal-based food for infants and young children	500 **0.5 ppm**

Commission Regulation (EU) 2018/290, of 26 February 2018

Malaysian Palm Oil Board licensing conditions

– Effective 1 January 2021

Parameters	Processed palm kernel oil	Processed palm oil	Effective date
GE (max.)	1.0 ppm	1.0 ppm	1 January 2021
3-MCPDE (max.)	1.25 ppm	2.5 ppm	1 January 2021 until 31 December 2021
		1.25 ppm*	1 January 2022

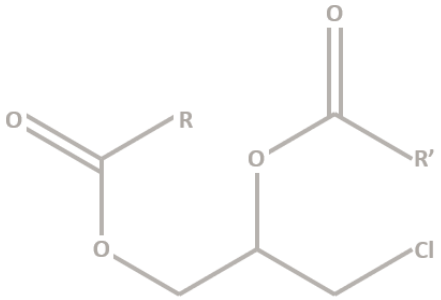
* Effective date for integrated refineries, exporters and importers is 1 January 2022. The effective date for independent refineries is 1 January 2023.

Challenges in 3-MCPD/GE mitigation

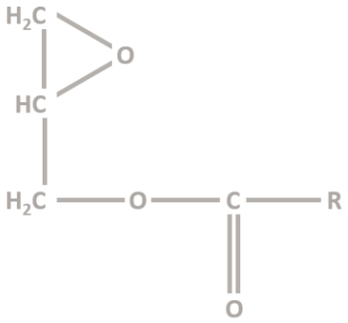
Factors contributing to 3-MCPDE and GE formation

– Chloride and high temperature

3-MCPDE molecule



GE molecule



- 3-MCPD and its esters are formed in heat-processed, fatty foods from glycerols or acylglycerides **in the presence of chloride ions**. Much of the 3-MCPDE found in foods is present as fatty acyl esters.
- Factors contributing to 3-MCPDE in refining of palm oil:
  - Presence of chloride in the crude palm oil (CPO), bleaching clay and steam
  - Acid degumming and acid-activated bleaching clay
  - High temperature during deodorization

- GE is formed from **diacylglyceride (DAG)** and monoacylglycerols (MAG), at temperatures above 230°C. GE is correlated with DAG content.
  - DAG in palm oil is between 6–12% whereas normal seed oil is 1–5%

Beware of GE migration into palm olein fractions

What happens in the dry fractionation process

- RBD* palm oil GE = 0.6 ppm
- Palm olein IV 56 GE = 0.75 ppm
- Palm olein IV 64 GE = 0.9 ppm

By regulation GE < 1 ppm

GE suggested for RBD palm oil
GE = 0.5 to 0.6 ppm

* RBD = Refined, bleached and deodorized

Process challenges

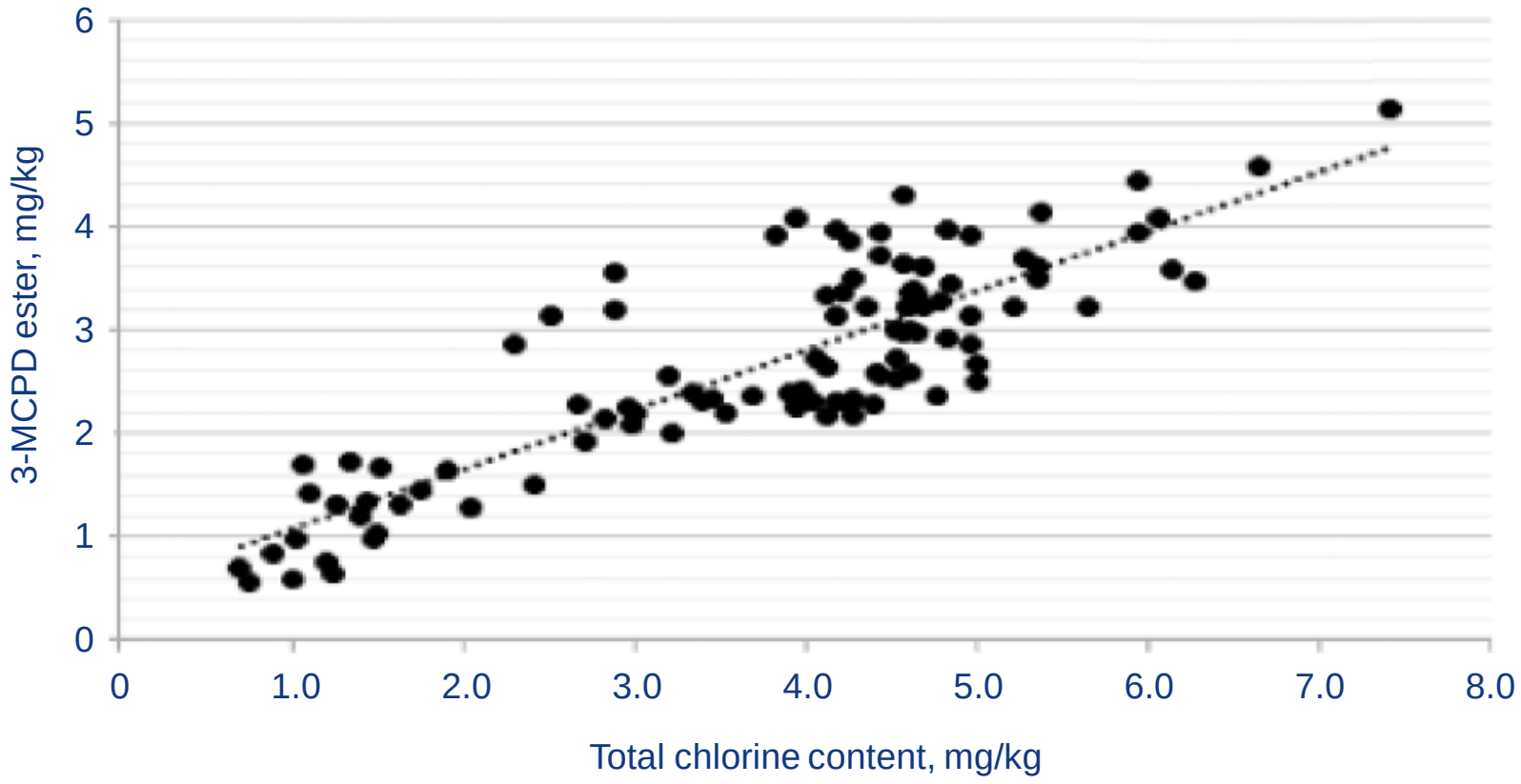
– 3-MCPD and GE mitigations

- Where and how to reduce chloride content to minimize 3-MCPD formation?
- How to fit in 3-MCPD and GE mitigation into an existing site?
- How to choose between the available GE mitigation options?
- How to prepare for stricter regulations of the maximum content of these contaminants in the future?

3-MCPD mitigation

Does chloride have a direct effect on 3-MCPDE levels?

– Test conducted in refinery with different chloride levels



Choosing the right mitigation method

– Which method is best for you?

Mitigation approaches

Plantations

- Reduce chlorine in fresh palm fruit bunches by changing fertilizers used
- Reduce DAG in palm oil by ensuring milling within 48 hours – improve quality of crude palm oil

Mills

- Wash fresh palm fruit bunches to remove chlorine precursor
- Fresh palm fruit bunches sterilization with steam without chlorine
- Wash fresh crude palm oil with slightly alkaline water

Refineries

- Wash the crude palm oil as the refinery and minimize residence time and temperature during deodorization to the extent possible

Malaysian Palm Oil Board Circular

– 30 October 2019

Quality specifications for crude palm oil

Specification	Standard quality
Free fatty acid (FFA) (as palmitic), % max.	5.0
Moistures and impurities (M&I), % max.	0.25
DOBI, min.	2.31
Chlorine (Cl), max.	2.0 ppm

Source: MPOB Circular No. 01/2019

Level of total chloride in palm oil products

Sample	Average (ppm)	Range (ppm)
Crude palm oil	7.293 ± 5.988	2.623 to 15.584

We have some gaps to cover

Crude palm oil quality in different streams

– Premium crude palm oil specification vs. oil from recovered streams

Quality	Crude palm oil	Condensate oil	Empty fruit bunch juice
Free fatty acids (%)	3% max.	18.3–30.2%	14.4–21.8%
Deterioration of Bleachability Index (DOBI)	2.8 min.	0.95–1.04	1.05–1.67
Chloride (ppm)	<2	41.7–53.8	20.5–41.7
Phosphates (ppm)	<10	70.5–112	89–153

Proven crude palm oil washing track record

– Alfa Laval presence in the South-East Asian region

34 crude palm oil washing systems sold since 2017

Mill 300 tons per day	Mill 600 tons per day	Refinery 100–1000 tons per day	Refinery 1000–3000 tons per day
• IOI palm oil mill • Unique palm oil mill • Boustead palm oil mill • IJM Edible Oils	• Sarawak Oil Palms • Kim Loong • Classic Segamat	• PGEO Group • Wilmar Group • Sime Darby Group • International Oil Group	• International Oil Group • Patum Vegetable Oil

Up to 84% of chloride reduction post-washing

– Actual field results from a crude palm oil washing installation at a palm oil mill

Sample date	CPO total chloride		Percentage Cl reduction (%)	Treated water total chloride (ppm)	Wastewater total chloride (ppm)
	Feed CPO	Washed CPO			
6/10/2018	5.952	0.626	89.48	8.576	93.562
11/10/2018	3.665	0.669	81.75	6.409	57.641
24/10/2018	4.260	0.408	90.42	7.497	80.459
27/10/2018	4.295	0.430	89.99	7.708	82.881
6/04/2019	11.298	2.252	80.07	6.333	56.836
20/05/2019	10.091	2.196	78.24	7.673	94.507
14/06/2019	6.317	1.021	83.84	7.683	53.664
15/06/2019	8.796	2.486	71.74	7.639	87.410
17/06/2019	11.857	1.183	90.02	9.313	67.748
Average	**7.392**	**1.252**	**83.95**	**7.648**	**74.968**

3-MCPDE/PIPOC2019/CPO washing results

Mass balance for crude palm oil washing

– Premium quality oil with low chloride content is the ultimate goal

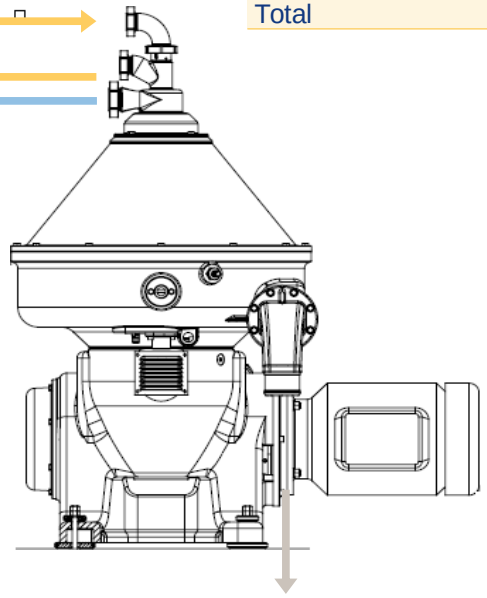
Crude palm oil in (A)	mt/hr
CPO	11.935
Moisture	0.053
Dirt	0.012
Total	12.000

Wash water (D)	0.96 mt/hr

Total feed	mt/hr
CPO	11.935
Moisture	0.013
Dirt	0.012
Total	12.960

Crude palm oil out (B)	mt/hr
CPO	11.926
Moisture	0.064
Dirt	0.001
Total	11.991

Washed water	mt/hr	%
Moisture	0.936	98.02
Oil	0.010	1.00
Dirt	0.009	0.98
Total	0.955	100.00



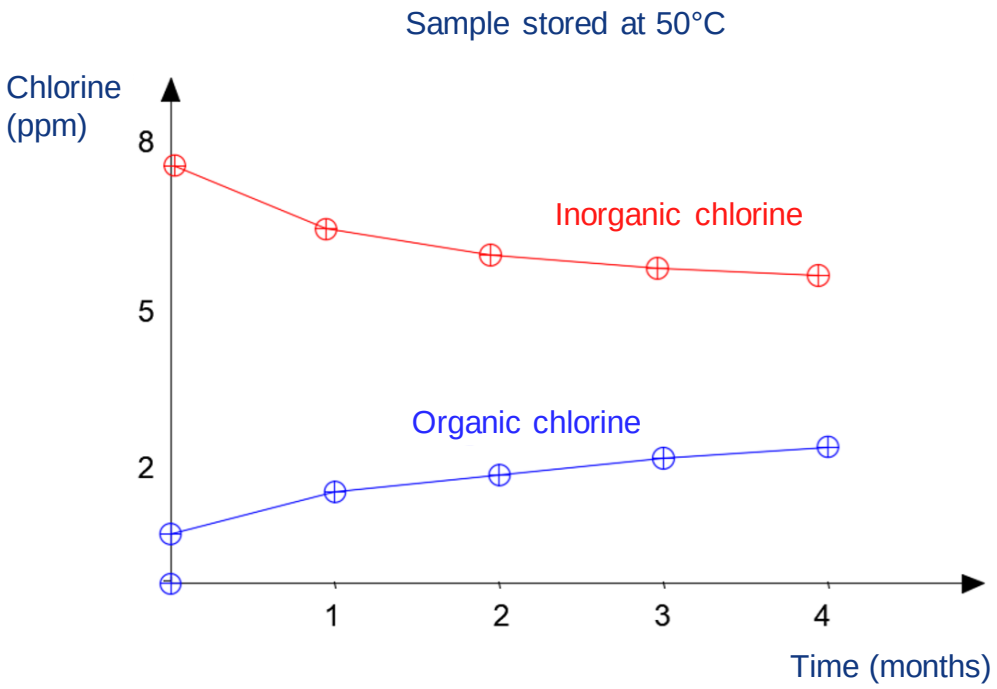
Water discharge (C)	0.0144 mt/hr

Oil losses to fresh palm fruit: 0.0159%

Oil losses are expected, but negligible compared to overall mill losses

Storage time impacts oil quality

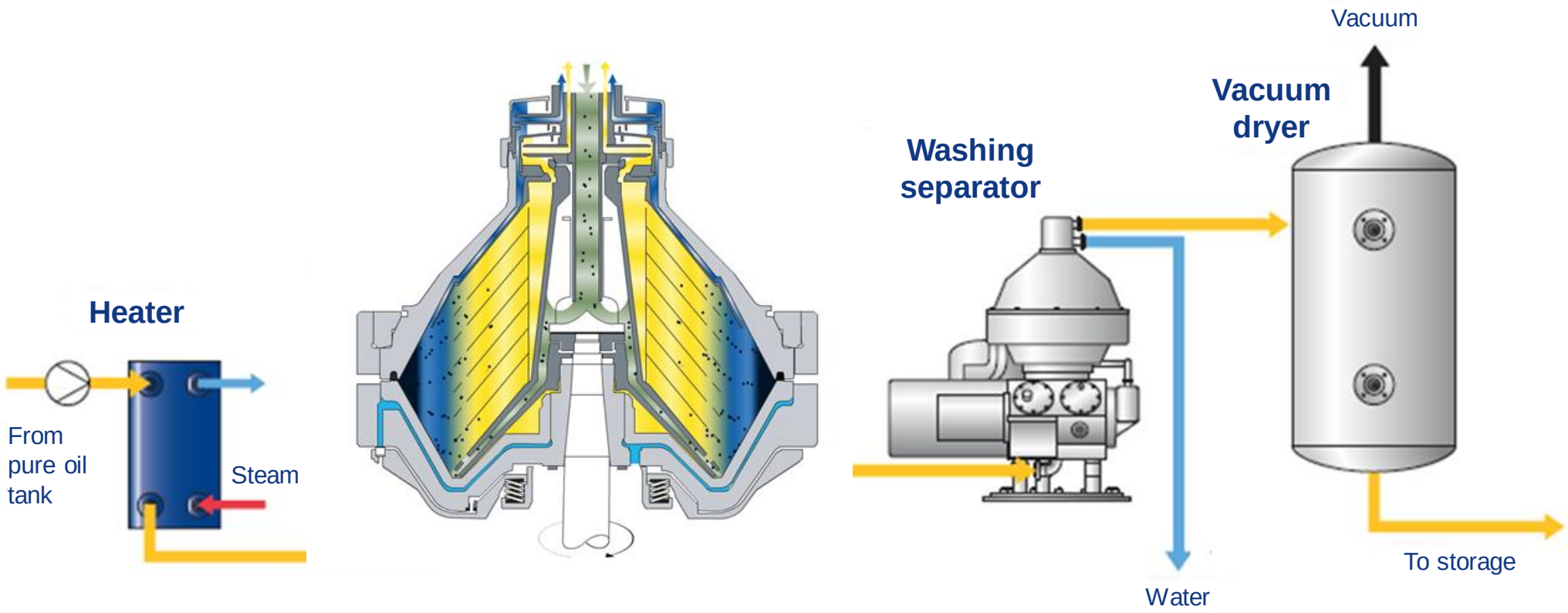
– Longer storage time = higher organic chloride content and lower inorganic chloride content



Time: Consider the effect of long holding time and transit time on chloride formation

* Study done by a refinery in Italy

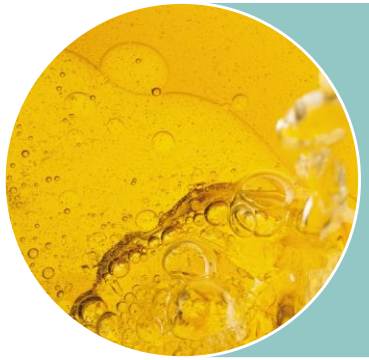
Simple, powerful and efficient CPO washing



Considerations: CPO washing for 3-MCPDE mitigation

Mills

- Early removal of chlorides most effective
- Overall lower utility cost
- Evaluate equipment maintenance cost (less cost if displacing existing purifiers)
- Easier for effluent handling
- Existing vacuum system can be used



Refineries

- Ability to receive crude palm oil from various sources
- Ability to handle high processing volume
- Centralized test equipment
- Easier access to skilled workers
- Need to install a new vacuum system

GE mitigation

Glycidyl ester contributing factors

Contributing factors

- High diacylglycerides (DAG)
- High deodorizing temperature (>220°C)
- Long retention time in deodorizer
- Hydrolysis at high temperature with steam effect

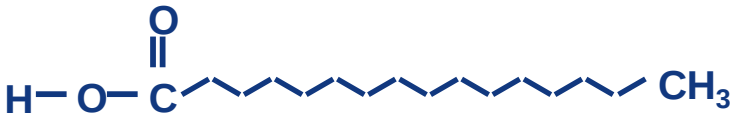
	Deodorizing temperature		
DAG	**215°C**	**225°C**	**250°C**
3%	0.6–1.0	2.2–3.5	3.0–7.5
5%	1.0–2.5	1.5–4.0	6–10
7%	1.5–3.5	2.5–5.0	9–15

Glycidyl ester (ppm) formed as function of DAG content and temperature.

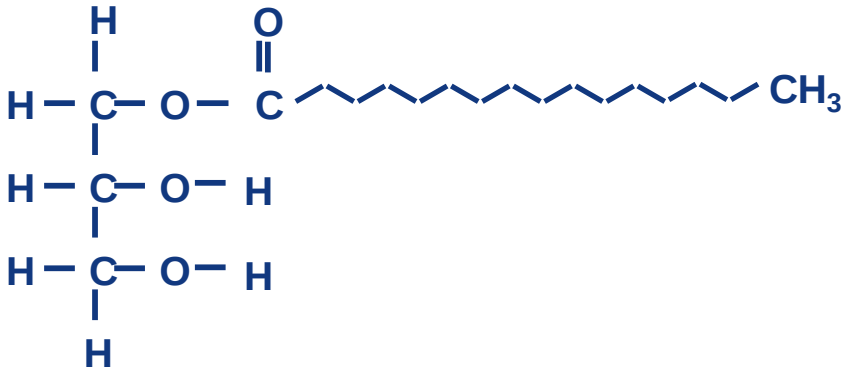
Free fatty acid, monoglyceride and glycidyl ester

– Light molecules

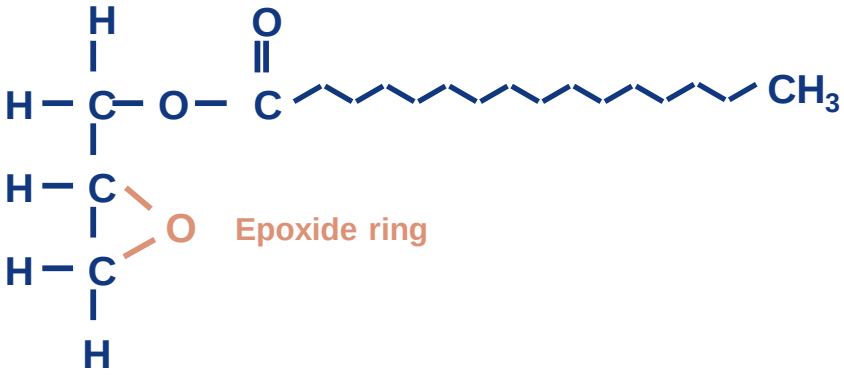
Free fatty acid (FFA)



Monoglyceride (MAG)



Glycidyl ester (GE)

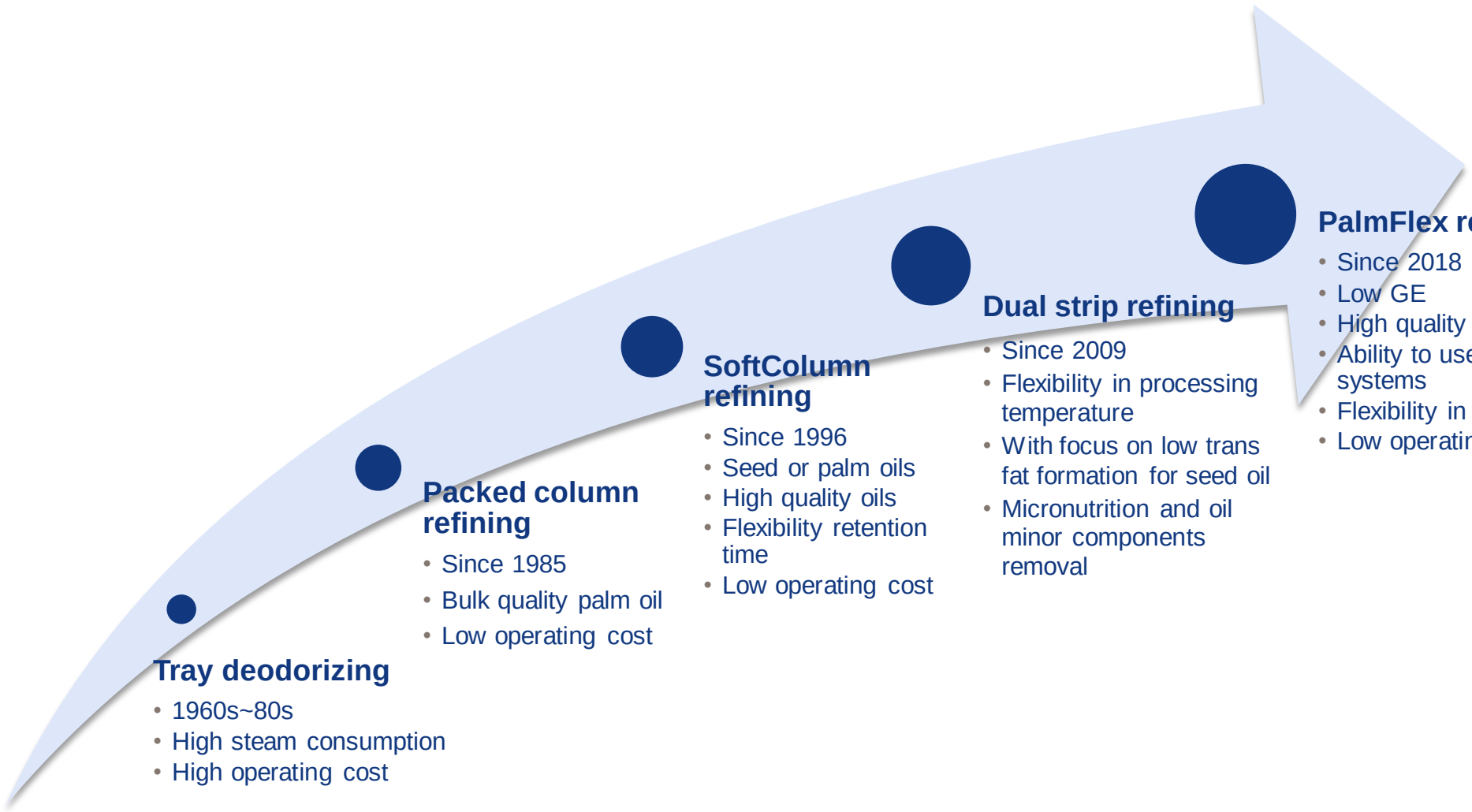


Glycidol ester mitigation methods

Method	Comment
Minimize formation in the deodorizer: limit temperature and residence time	Not sufficient to reach levels well below 0.5/1 ppm for palm oils or similar, especially for low colour product requirements
Re-refining with activated bleaching earth followed by mild deodorization	Can reach 0.2–0.3 ppm, but post-refining has high OPEX and CAPEX and does not completely eliminate GEs
Direct stripping	Direct GE stripping can reach levels below 0.5 ppm subject to GE content in feed
Alfa Laval ZeroGE™	…

Development of Alfa Laval deodorizing technology

– A commitment to continuous development



Tray deodorizing
- 1960s~80s
- High steam consumption
- High operating cost

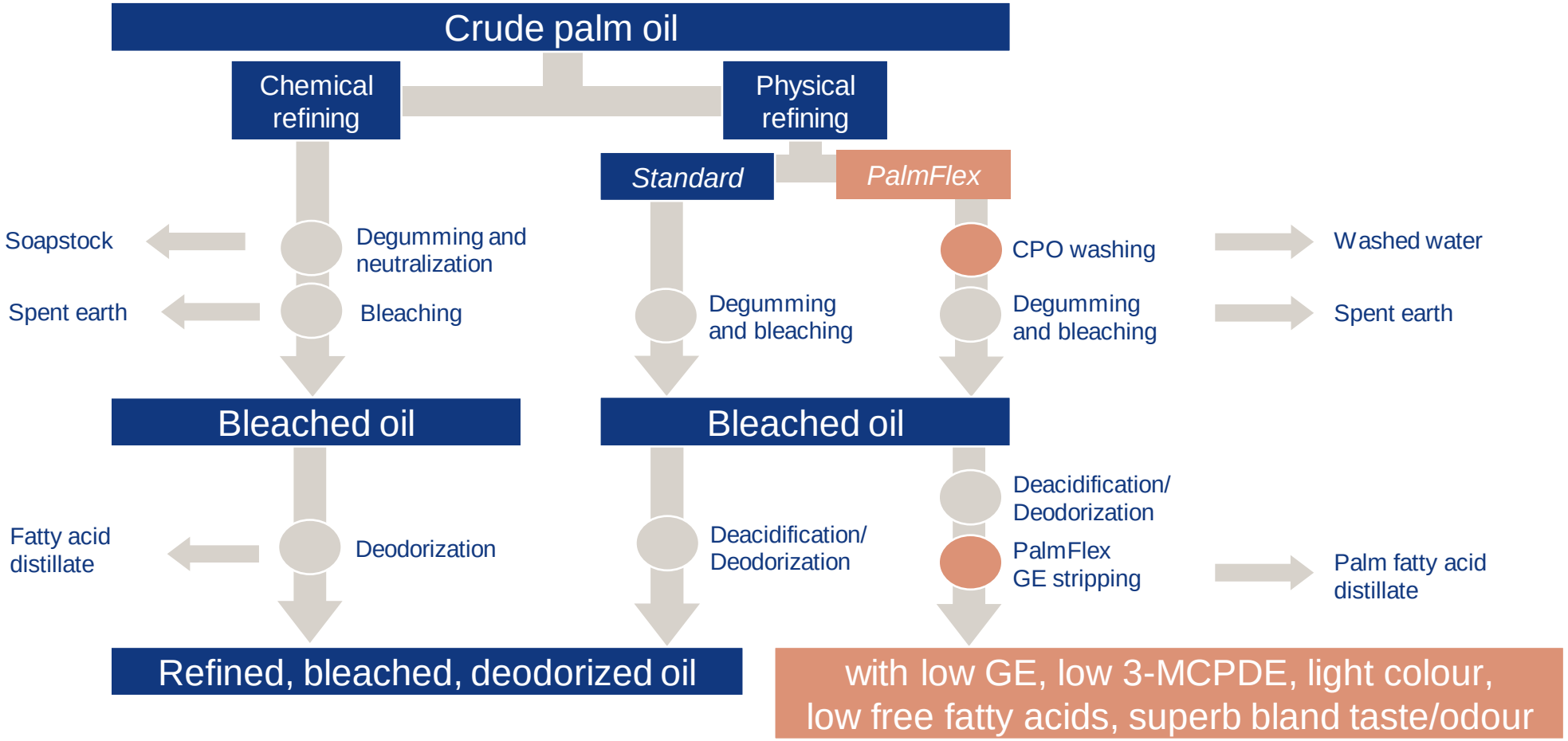
Packed column refining
- Since 1985
- Bulk quality palm oil
- Low operating cost

SoftColumn refining
- Since 1996
- Seed or palm oils
- High quality oils
- Flexibility retention time
- Low operating cost

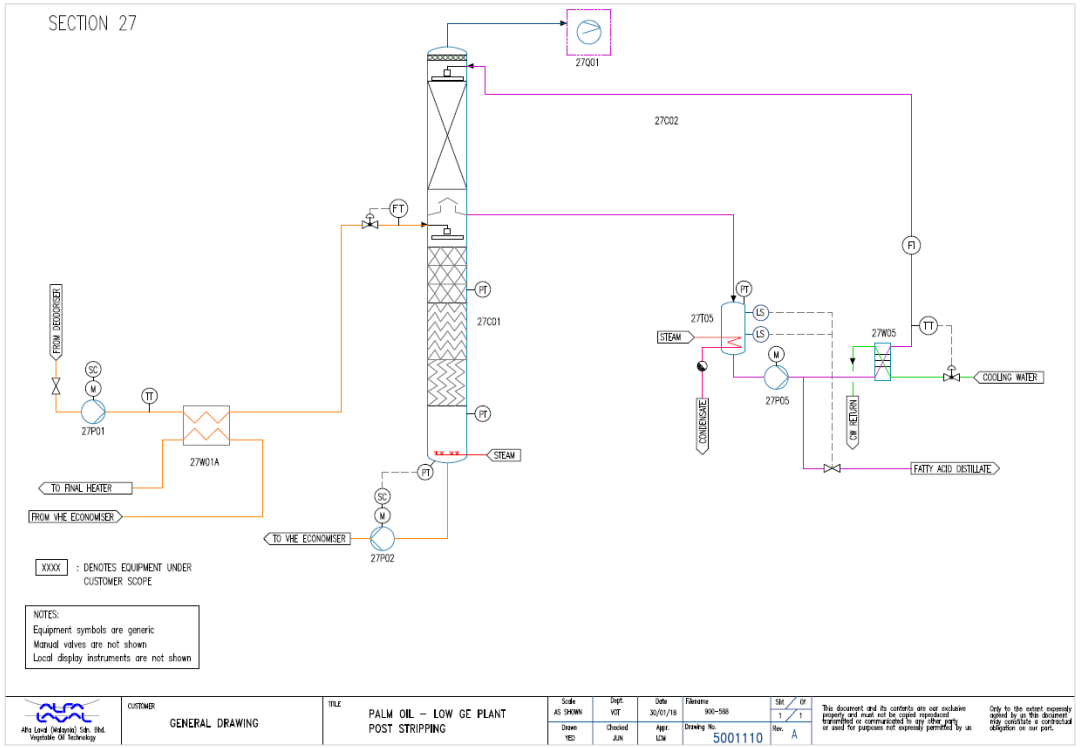
Dual strip refining
- Since 2009
- Flexibility in processing temperature
- With focus on low trans fat formation for seed oil
- Micronutrition and oil minor components removal

PalmFlex refining
- Since 2018
- Low GE
- High quality palm oil
- Ability to use with low vacuum systems
- Flexibility in operation
- Low operating cost

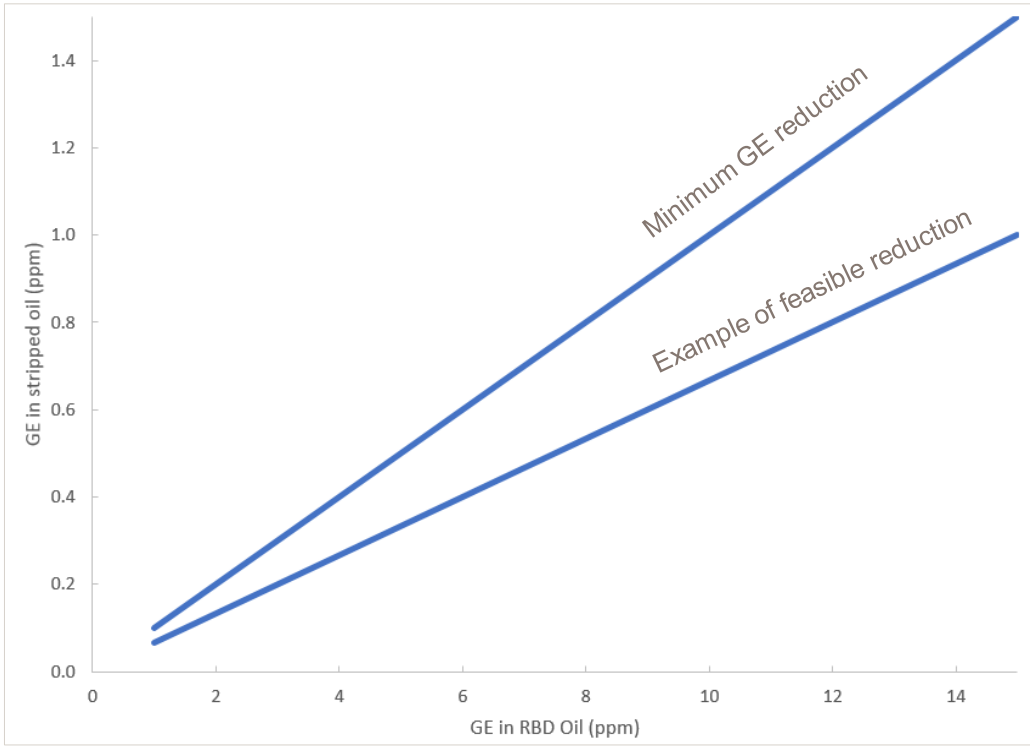
Alfa Laval PalmFlex – the optimum refining route



GE stripper designed specifically for GE removal



Performance based on commercial scale plant data and Alfa Laval's proprietary lipid property library and the process simulator PRO II from SimSci.



References

1 L. P. Cunico, R. Ceriani, B. Sarup, J. P. O'Connell, R. Gani, "Data, analysis and modeling of physical properties for process design of systems involving lipids", Fluid Phase Equilibria, 362, p 318ff (2014).

2 R. Ceriani, R. Gani, Y. A. Liu, "Prediction of vapor pressure and heats of vaporization of edible oil/fat compounds by group contribution". Fluid Phase Equilibria, 337, p 53ff (2012).

Great flexibility with Alfa Laval PalmFlex refining

1

Direct GE stripper with GE <0.5 ppm, low colour, low FFA, superb bland and odourless oil

No double refining needed

2

Bulk refining for low colour, low FFA, and superb bland and odourless oil

3

With high FFA feed, the plant can still operate at the rated capacity based on Palm Oil Refiners Association of Malaysia (PORAM) specifications

4

The plant can also operate above rated capacity with PORAM specifications

5

The plant can also operate at 70% turn-down without having a big impact on the per-ton cost

Achieve the highest quality

– Optimal refined, bleached and deodorized (RBD) palm oil

Quality of RBD Palm Oil	Standard	PalmFlex
Free fatty acids (FFA)	Max. 0.05%	0.03~0.04%
Moisture and volatile matter	Max. 0.05%	Max. 0.03% (with refined oil dryer)
Colour (Lovibond 5¼" cell)	Max. 2.5 red / 25 yellow	Max. 2.0 red / 20 yellow
Peroxide value	0	0
Taste / odour	Bland / odourless	Superb bland / odourless
Palm fatty acid distillate purity (based on 5% FFA in feed)	Min. 89%	Min. 89%
3-MCPDE	4–6 ppm	< 1 ppm (with washing)
Glycidyl esters (GE)	8–15 ppm	0.3~0.5 ppm (with GE stripper)

Note: Final oil quality may vary subject to feedstock and process variation.

How PalmFlex meets large refinery expectations

- Consistent high-quality oil
- Continuous operation
- Flexibility in operating choices
- Low operating cost with high heat recovery
- Safe and easy operation
- Strong aftersales, service and support

Summary of benefits

Alfa Laval in 3-MCPD and GE mitigation technology

– Summary of benefits

- Highly efficient chloride **reduction** at the mill and at the refinery with **minimum oil losses**
- Proven Alfa Laval PalmFlex refining technology delivers **highest oil quality** at **low operating costs** while meeting stringent **food safety regulations**

Q&As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