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# 3-MCPD and GE mitigation in palm oil processing

- Webinar 7 May 2020

Alexey Shevchenko

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#### Agenda



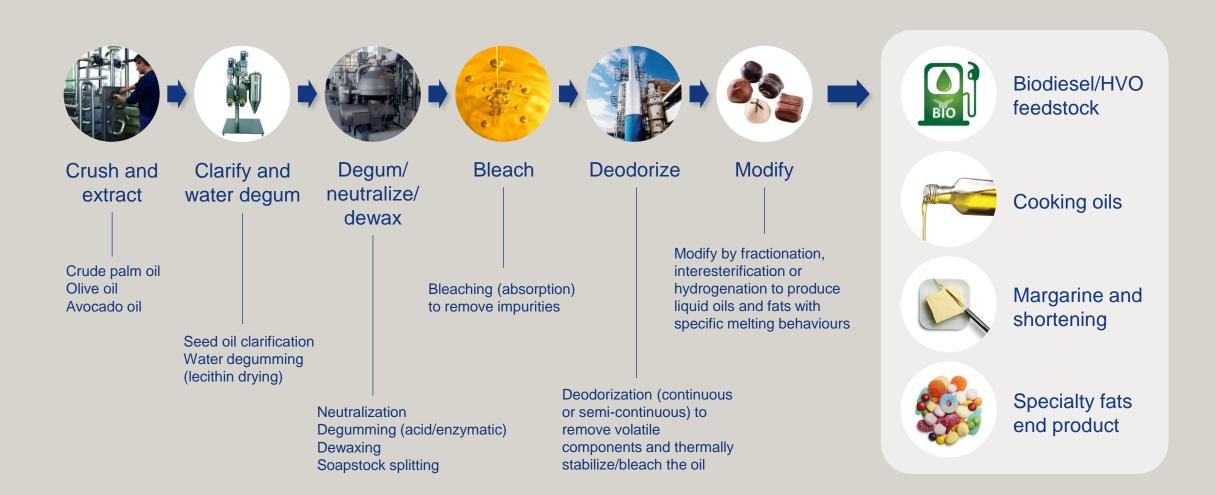
- A short introduction to Alfa Laval's edible oil portfolio
- Edible oil industry trends and focus
- Introduction to the 3-MCPD and GE issues
- 3-MCPD mitigation in more depth
- Process routes to GE mitigation
- Conclusion

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### Our edible oil process line portfolio

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- Comprehensive solutions



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# Industry trends

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#### Industry trends and focus

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- 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

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# Introduction to 3-MCPD and GE issues

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#### What are 3-MCPDE and GE?





#### Why limit 3-MCPDE and GE exposure?



#### **Classified as process contaminants**

• 3-monochloropropane diol (3-MCPD)

• 3-monochloropropane diol ester (3-MCPDE)

Possibly carcinogenic to humans<sup>1</sup>

Harmful to kidneys (EFSA<sup>2</sup> report 2016)

Glycidyl ester (GE)

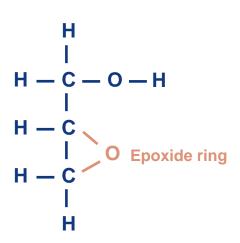
Probably carcinogenic to humans<sup>1</sup>

<sup>&</sup>lt;sup>1</sup> Classification by International Agency for Research on Cancer

<sup>&</sup>lt;sup>2</sup> 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



Known food contaminant in hydrolyzed vegetable proteins (HVP) and found in a wide range of daily food

2009

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

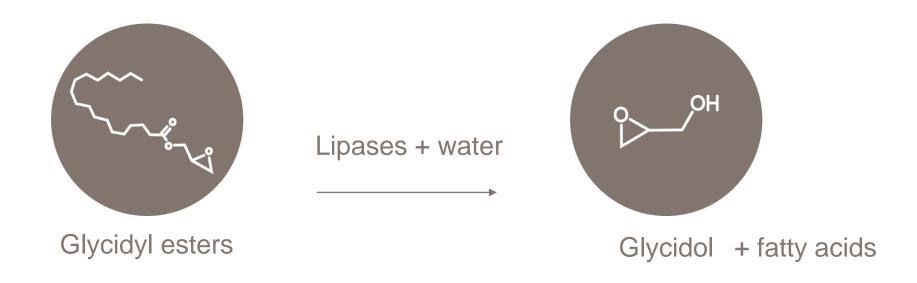
Jan 2018

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





GEs are rapidly digested by gut lipases to form glycidol. Consequently, GEs should be considered as sources of glycidol exposure.<sup>1</sup>

<sup>&</sup>lt;sup>1</sup> 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 <b>1.0 ppm</b>
Vegetable oils and fats destined for the production of baby food and processed cereal-based food for infants and young children	500 <b>0.5 ppm</b>

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



### Malaysian Palm Oil Board licensing conditions

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- 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	1.25 ppm	2.5 ppm	1 January 2021 until 31 December 2021
		1.25 ppm*	1 January 2022

<sup>\*</sup> 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

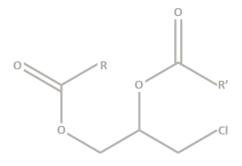
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#### Factors contributing to 3-MCPDE and GE formation



Chloride and high temperature

#### 3-MCPDE molecule



#### GE molecule

$$H_2C$$
 $O$ 
 $C$ 
 $R$ 
 $O$ 

- 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 64 GE = 0.9 ppm

By regulation GE < 1 ppm

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



<sup>\*</sup> RBD = Refined, bleached and deodorized

#### Process challenges

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- 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?

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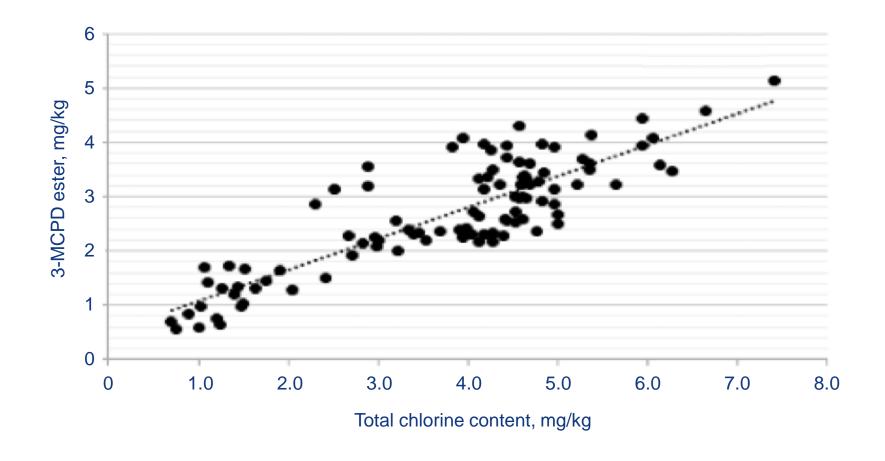


# 3-MCPD mitigation

#### 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 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

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### 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 (CI), 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

### Conventional Palm Oil Milling





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### Crude palm oil quality in different streams



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





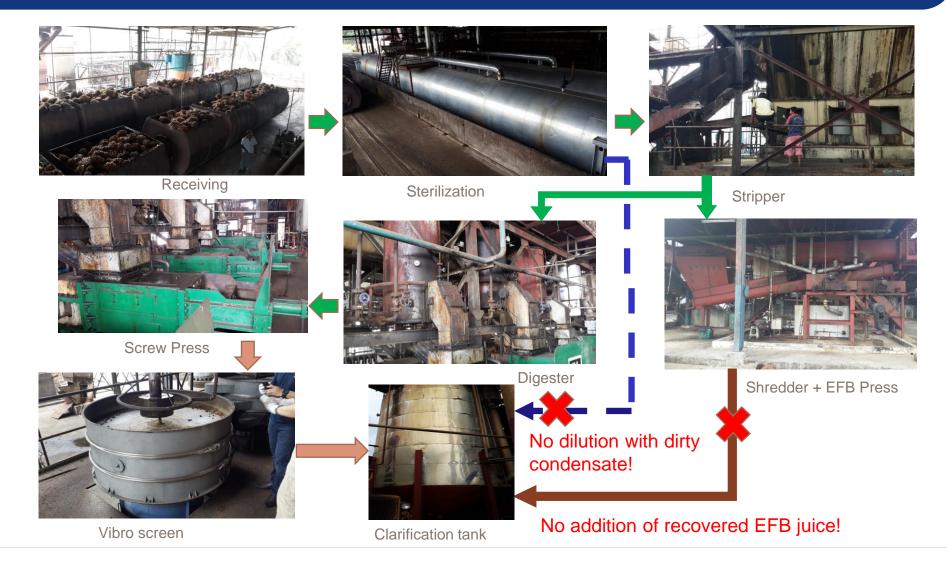


Quality	Crude palm oil	Condensate oil	Empty fruit bunch juice
Free fatty acids (%)	3% max.	18.3–30.2%	14.4–21.8%
Deterioration of Bleachability Index (DOBI)	2.8 min.	0.95–1.04	1.05–1.67
Chloride (ppm)	<2	41.7–53.8	20.5–41.7
Phosphates (ppm)	<10	70.5–112	89–153

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### Conventional Palm Oil Milling





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#### 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

- IOI palm oil mill
- Unique palm oil mill
- Boustead palm oil mill
- IJM Edible Oils

## Mill 600 tons per day

- Sarawak Oil Palms
- Kim Loong
- Classic Segamat

#### Refinery 100–1000 tons per day

- PGEO Group
- Wilmar Group
- Sime Darby Group
- International Oil Group

#### Refinery 1000–3000 tons per day

- International Oil Group
- Patum VegetableOil

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### Up to 84% of chloride reduction post-washing



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

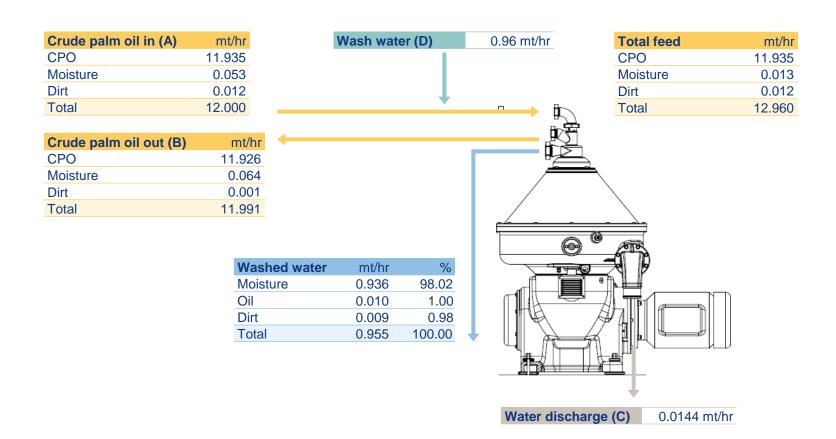
Sample date	CPO tota	l chloride	Percentage CI		Treated water total		Wastewater total
	Feed CPO	Washed CPO		reduction (%)	chloride (pp	m)	chloride (ppm)
6/10/2018	5.952	0.626		89.48	8.576		93.562
11/10/2018	3.665	0.669		81.75	6.409		57.641
24/10/2018	4.260	0.408		90.42	7.497		80.459
27/10/2018	4.295	0.430		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



Oil losses to fresh palm fruit: 0.0159%

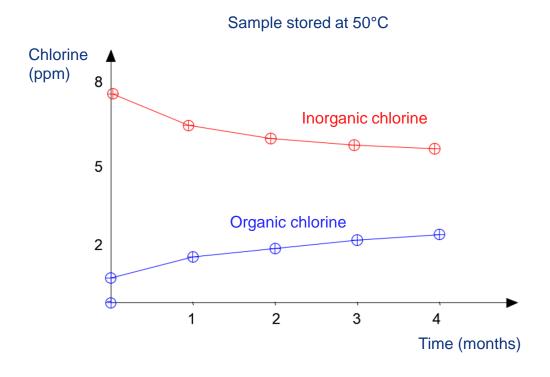
Oil losses are expected, but negligible compared to overall mill losses

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### Storage time impacts oil quality



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



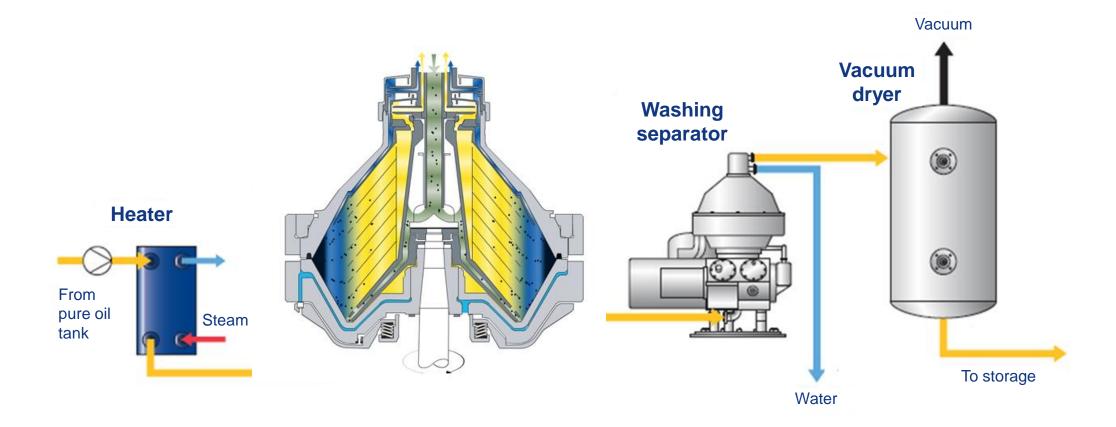
**Time:** Consider the effect of long holding time and transit time on chloride formation

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<sup>\*</sup> Study done by a refinery in Italy

### Simple, powerful and efficient CPO washing





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#### 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

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# **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.

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#### Free fatty acid, monoglyceride and glycidyl ester



Light molecules

### 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™	



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#### Development of Alfa Laval deodorizing technology



- A commitment to continuous development



### 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

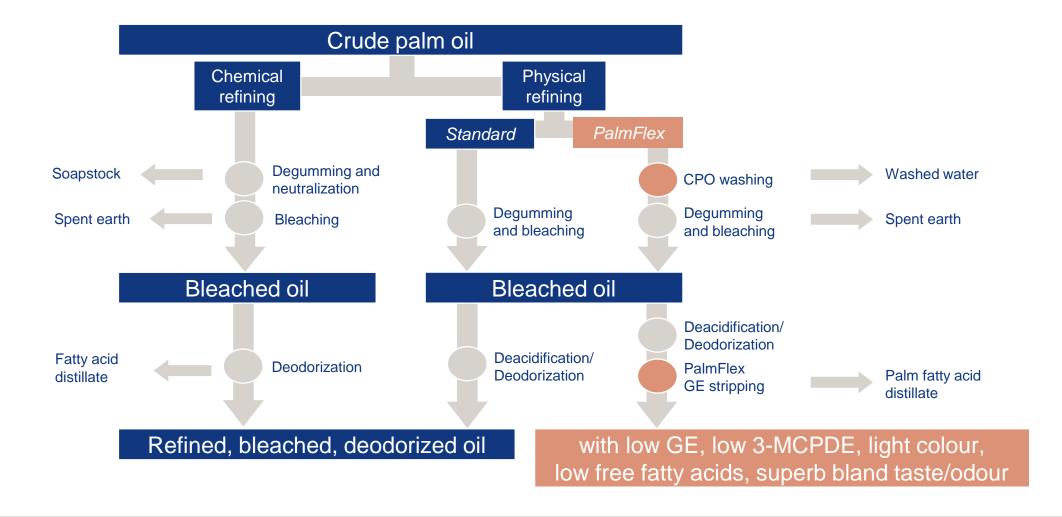
#### Tray deodorizing

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

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#### Alfa Laval PalmFlex – the optimum refining route

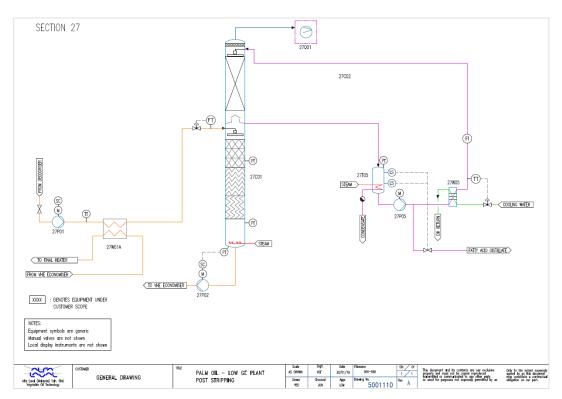




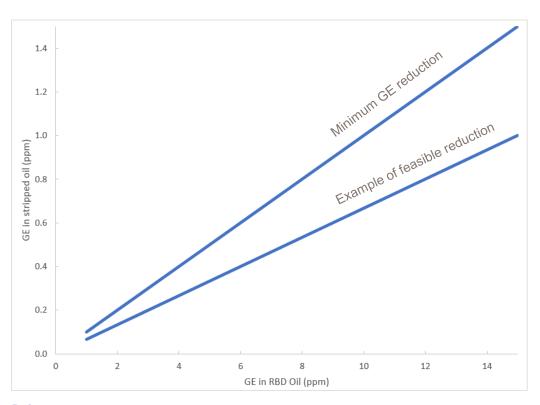
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#### GE stripper designed specifically for GE removal





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).

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#### 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



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### 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 51/4" 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.

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#### 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

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#### 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

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# Q&As

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