3-MCPD and GE mitigation in palm oil processing

- Webinar 7 May 2020
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**

**Environmental footprint**
Focus on image, legislation and utility cost

**Water and energy savings**

**Continued investments in plant infrastructure**

**Significant rise in vegan and vegetarian population**

**More affordable, raw plant-based materials**

**Increased use of plant-based margarines**

**Demand for low-fat bakery and confectionery products**

**More health-conscious consumers**

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

**More affordable, raw plant-based materials**

**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**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Classification</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-monochloropropane diol (3-MCPD)</td>
<td>Possibly carcinogenic to humans(^1)</td>
<td></td>
</tr>
<tr>
<td>3-monochloropropane diol ester (3-MCPDE)</td>
<td>Harmful to kidneys (EFSA(^2) report 2016)</td>
<td></td>
</tr>
<tr>
<td>Glycidyl ester (GE)</td>
<td>Probably carcinogenic to humans(^1)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Classification by International Agency for Research on Cancer  
\(^2\) European Food Safety Authority
Glycidol and glycidyl ester

Glycidol

Glycerol backbone

Epoxide ring

1 bonded fatty acid

Epoxide ring formed at temp >220°C

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

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

EU legislation on GE affects supply chain

<table>
<thead>
<tr>
<th>Glycidyl fatty acid esters expressed as glycidol</th>
<th>Maximum level µg/kg</th>
</tr>
</thead>
</table>
| 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**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Processed palm kernel oil</th>
<th>Processed palm oil</th>
<th>Effective date</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE (max.)</td>
<td>1.0 ppm</td>
<td>1.0 ppm</td>
<td>1 January 2021</td>
</tr>
<tr>
<td>3-MCPDE (max.)</td>
<td>1.25 ppm</td>
<td>2.5 ppm</td>
<td>1 January 2021 until 31 December 2021</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.25 ppm*</td>
<td>1 January 2022</td>
</tr>
</tbody>
</table>

* 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-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

![Graph showing the relationship between Total chlorine content (mg/kg) and 3-MCPD ester (mg/kg). The graph indicates a positive correlation between the two variables.](image-url)
Choosing the right mitigation method

- Which method is best for you?

### Mitigation approaches

<table>
<thead>
<tr>
<th>Plantations</th>
<th>Mills</th>
<th>Refineries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce chlorine in fresh palm fruit bunches by changing fertilizers used</td>
<td>Wash fresh palm fruit bunches to remove chlorine precursor</td>
<td>Wash the crude palm oil as the refinery and minimize residence time and temperature during deodorization to the extent possible</td>
</tr>
<tr>
<td>Reduce DAG in palm oil by ensuring milling within 48 hours – improve quality of crude palm oil</td>
<td>Fresh palm fruit bunches sterilization with steam without chlorine</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wash fresh crude palm oil with slightly alkaline water</td>
<td></td>
</tr>
</tbody>
</table>
Quality specifications for crude palm oil

<table>
<thead>
<tr>
<th>Specification</th>
<th>Standard quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free fatty acid (FFA) (as palmitic), % max.</td>
<td>5.0</td>
</tr>
<tr>
<td>Moistures and impurities (M&amp;I), % max.</td>
<td>0.25</td>
</tr>
<tr>
<td>DOBI, min.</td>
<td>2.31</td>
</tr>
<tr>
<td>Chlorine (Cl), max.</td>
<td>2.0 ppm</td>
</tr>
</tbody>
</table>

Source: MPOB Circular No. 01/2019

Level of total chloride in palm oil products

<table>
<thead>
<tr>
<th>Sample</th>
<th>Average (ppm)</th>
<th>Range (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude palm oil</td>
<td>7.293 ± 5.988</td>
<td>2.623 to 15.584</td>
</tr>
</tbody>
</table>

We have some gaps to cover
# Crude palm oil quality in different streams

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

<table>
<thead>
<tr>
<th>Quality</th>
<th>Crude palm oil</th>
<th>Condensate oil</th>
<th>Empty fruit bunch juice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free fatty acids (%)</td>
<td>3% max.</td>
<td>18.3–30.2%</td>
<td>14.4–21.8%</td>
</tr>
<tr>
<td>Deterioration of Bleachability Index (DOBI)</td>
<td>2.8 min.</td>
<td>0.95–1.04</td>
<td>1.05–1.67</td>
</tr>
<tr>
<td>Chloride (ppm)</td>
<td>&lt;2</td>
<td>41.7–53.8</td>
<td>20.5–41.7</td>
</tr>
<tr>
<td>Phosphates (ppm)</td>
<td>&lt;10</td>
<td>70.5–112</td>
<td>89–153</td>
</tr>
</tbody>
</table>
## 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

<table>
<thead>
<tr>
<th>Mill 300 tons per day</th>
<th>Mill 600 tons per day</th>
<th>Refinery 100–1000 tons per day</th>
<th>Refinery 1000–3000 tons per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOI palm oil mill</td>
<td>Sarawak Oil Palms</td>
<td>PGEO Group</td>
<td>International Oil Group</td>
</tr>
<tr>
<td>Unique palm oil mill</td>
<td>Kim Loong</td>
<td>Wilmar Group</td>
<td>Patum Vegetable Oil</td>
</tr>
<tr>
<td>Boustead palm oil mill</td>
<td>Classic Segamat</td>
<td>Sime Darby Group</td>
<td></td>
</tr>
<tr>
<td>IJM Edible Oils</td>
<td></td>
<td>International Oil Group</td>
<td></td>
</tr>
</tbody>
</table>

- 34 crude palm oil washing systems sold since 2017
Up to 84% of chloride reduction post-washing
- Actual field results from a crude palm oil washing installation at a palm oil mill

<table>
<thead>
<tr>
<th>Sample date</th>
<th>CPO total chloride</th>
<th>Percentage CI reduction (%)</th>
<th>Treated water total chloride (ppm)</th>
<th>Wastewater total chloride (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feed CPO</td>
<td>Washed CPO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/10/2018</td>
<td>5.952</td>
<td>0.626</td>
<td>89.48</td>
<td>8.576</td>
</tr>
<tr>
<td>11/10/2018</td>
<td>3.665</td>
<td>0.669</td>
<td>81.75</td>
<td>6.409</td>
</tr>
<tr>
<td>24/10/2018</td>
<td>4.260</td>
<td>0.408</td>
<td>90.42</td>
<td>7.497</td>
</tr>
<tr>
<td>27/10/2018</td>
<td>4.295</td>
<td>0.430</td>
<td>89.99</td>
<td>7.708</td>
</tr>
<tr>
<td>6/04/2019</td>
<td>11.298</td>
<td>2.252</td>
<td>80.07</td>
<td>6.333</td>
</tr>
<tr>
<td>20/05/2019</td>
<td>10.091</td>
<td>2.196</td>
<td>78.24</td>
<td>7.673</td>
</tr>
<tr>
<td>14/06/2019</td>
<td>6.317</td>
<td>1.021</td>
<td>83.84</td>
<td>7.683</td>
</tr>
<tr>
<td>15/06/2019</td>
<td>8.796</td>
<td>2.486</td>
<td>71.74</td>
<td>7.639</td>
</tr>
<tr>
<td>17/06/2019</td>
<td>11.857</td>
<td>1.183</td>
<td>90.02</td>
<td>9.313</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>7.392</strong></td>
<td><strong>1.252</strong></td>
<td><strong>83.95</strong></td>
<td><strong>7.648</strong></td>
</tr>
</tbody>
</table>

3-MCPDE/PIPOC2019/CPO washing results
Mass balance for crude palm oil washing

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

<table>
<thead>
<tr>
<th>Crude palm oil in (A)</th>
<th>mt/hr</th>
<th>Crude palm oil out (B)</th>
<th>mt/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPO</td>
<td>11.935</td>
<td>CPO</td>
<td>11.926</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.053</td>
<td>Moisture</td>
<td>0.064</td>
</tr>
<tr>
<td>Dirt</td>
<td>0.012</td>
<td>Dirt</td>
<td>0.001</td>
</tr>
<tr>
<td>Total</td>
<td>12.000</td>
<td>Total</td>
<td>11.991</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Washed water</th>
<th>mt/hr</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>0.936</td>
<td>98.02</td>
</tr>
<tr>
<td>Oil</td>
<td>0.010</td>
<td>1.00</td>
</tr>
<tr>
<td>Dirt</td>
<td>0.009</td>
<td>0.98</td>
</tr>
<tr>
<td>Total</td>
<td>0.955</td>
<td>100.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total feed</th>
<th>mt/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPO</td>
<td>11.935</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.013</td>
</tr>
<tr>
<td>Dirt</td>
<td>0.012</td>
</tr>
<tr>
<td>Total</td>
<td>12.960</td>
</tr>
</tbody>
</table>

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

* Study done by a refinery in Italy

**Time:** Consider the effect of long holding time and transit time on chloride formation
Simple, powerful and efficient CPO washing

Heater

From pure oil tank

Steam

Water

Vacuum dryer

Vacuum

Washing separator

To storage

Pure oil tank

Reactor

Mixer
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

<table>
<thead>
<tr>
<th>DAG</th>
<th>215°C</th>
<th>225°C</th>
<th>250°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>3%</td>
<td>0.6–1.0</td>
<td>2.2–3.5</td>
<td>3.0–7.5</td>
</tr>
<tr>
<td>5%</td>
<td>1.0–2.5</td>
<td>1.5–4.0</td>
<td>6–10</td>
</tr>
<tr>
<td>7%</td>
<td>1.5–3.5</td>
<td>2.5–5.0</td>
<td>9–15</td>
</tr>
</tbody>
</table>

Glycidyl ester (ppm) formed as function of DAG content and temperature.
Free fatty acid, monoglyceride and glycidyl ester
- Light molecules

Free fatty acid (FFA)

\[
\begin{align*}
\text{H} - \text{O} - \text{C} - \ldots - \text{C} - \ldots - \text{O} - \text{CH}_3 \\
\end{align*}
\]

Monoglyceride (MAG)

\[
\begin{align*}
\text{H} - \text{C} - \text{O} - \text{C} - \ldots - \text{C} - \ldots - \text{O} - \text{CH}_3 \\
\text{H} - \text{C} - \text{O} - \text{H} \\
\text{H} - \text{C} - \text{O} - \text{H} \\
\text{H}
\end{align*}
\]

Glycidyl ester (GE)

\[
\begin{align*}
\text{H} - \text{C} - \text{O} - \text{C} - \ldots - \text{C} - \ldots - \text{O} - \text{CH}_3 \\
\text{H} - \text{C} - \text{O} - \text{H} \\
\text{H} - \text{C} - \text{O} - \text{H} \\
\text{H} \\
\end{align*}
\]

Epoxide ring
Glycidol ester mitigation methods

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

**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

Crude palm oil

Chemical refining

Degumming and neutralization

Bleaching

Soapstock

Spent earth

Physical refining

Degumming and bleaching

Bleached oil

Standard

PalmFlex

CPO washing

Degumming and bleaching

Washed water

Spent earth

Bleached oil

Deacidification/Deodorization

PalmFlex GE stripping

Palm fatty acid distillate

Refined, bleached, deodorized oil

with low GE, low 3-MCPDE, light colour, low free fatty acids, superb bland taste/odour

Fatty acid distillate

Deodorization

Washed water

Spent earth

Bleached oil

Deacidification/Deodorization

Palm fatty acid distillate

Refined, bleached, deodorized oil

with low GE, low 3-MCPDE, light colour, low free fatty acids, superb bland taste/odour
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
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

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

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
• 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