Mitigation of 3-MCPDE & GE Precursors in Palm Oil Mill
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Presentation Outline

COMPANY PROFILE
- An Integrated Plantation Company

PALM OIL MILLING PROCESS & CRUDE PALM OIL QUALITY
- Palm Oil Processing
- Crude Palm Oil Composition
- Crude Palm Oil Specification

3-MCPDE & GE FORMATION & FACTORS
- Formation
- Factors

MITIGATION STRATEGIES
- Reduction of 3-MCPDE Precursor
- Improvement of Oil Quality

CONCLUSION
COMPANY PROFILE

• SIME DARBY PLANTATION
  An Integrated Plantation Company
## Company Profile

*Integrated Plantation Company*

### Upstream

- **Oil palm estate**
- **Milling of FFB and processing & sales**
  - Milling of FFB into CPO and PK
  - Processing and sales of rubber and sugarcane
- **Others**
  - Cattle rearing and beef production

### Downstream

- **Refinery**
- **Food application**
- **Bulk and refined oils & fats**
  - Production and sales of refined oils and fats (which includes specialty and end-user oils and fats)
- **Oleochemicals, biodiesel products & derivatives**
  - Production and sales of oleochemicals, biodiesel products and derivatives

### Others

- **High-yielding genome seeds**
- **Renewables**

### R&D

- Focused on yield and productivity improvements, increasing revenue streams and developing sustainable practices while pursuing innovative strategies

### Renewables business

- Development of green technology and renewable energy which includes bio-based chemicals, biogas and composting

### Agribusiness

- Provision of agriculture products and services
PALM OIL MILLING PROCESS & CRUDE PALM OIL QUALITY

• Palm Oil Processing
• Crude Palm Oil Composition
• Crude Palm Oil Specification
Oil Extraction Rate (OER) = 20-22%
Oil Losses = 1.40-1.60%
Palm Oil Milling Process & Crude Palm Oil Quality

Crude Palm Oil Composition

- **Triacylglycerol (TAG), %**
  88 – 97

- **Diacylglycerol (DAG), %**
  3 – 7

- **Monoacylglycerol (MAG), %**
  0 – 1

- **Free fatty acid (FFA), %**
  1 – 5

- **Moistures Solid & Impurities, %**
  0.08 – 0.24

- **Tocopherols and tocotrienols, ppm**
  500 - 1100

- **Carotenoids, ppm**
  400 - 800

- **Phytosterols, ppm**
  300 - 600

- **Squalene, ppm**
  200 - 500

- **Phospholipids, ppm**
  3 - 140

- **Metals, Copper and Iron, ppm**
  1 – 10
## Palm Oil Milling Process & Crude Palm Oil Quality

### Crude Palm Oil Specification

<table>
<thead>
<tr>
<th>PORAM Specifications</th>
<th>Characteristics, Quality Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Free fatty acid (as palmitic), % max 5.0</td>
</tr>
<tr>
<td>02</td>
<td>Moisture &amp; impurities, % max 0.25</td>
</tr>
<tr>
<td>03</td>
<td>Degree of Bleachability Index (DOBI), min 2.3</td>
</tr>
<tr>
<td>04</td>
<td>*Chlorine, ppm max 2.0</td>
</tr>
<tr>
<td>05</td>
<td>**Phosphorus, ppm max 10.0</td>
</tr>
</tbody>
</table>

* Additional quality requirement for CPO by January 2020 but was **deferred until further notice.**

** Proposed as guideline.
Rising concern by the food safety authority on the presence of common probable carcinogenic food contaminants in edible oil.

Joint FAO/WHO Expert Committee on Food Additives (JECFA) proposed Provisional Maximum Tolerable Daily Intake (PMTDI) of 4 μg/kg body weight for 3-MCPDEs, either single or in combination with the GEs\textsuperscript{2,3}.

Studies found that refined palm oil contains the highest amount of 3-MCPDEs and GEs\textsuperscript{17}.

From 2021, EFSA proposed to limit the presence this food contaminants in edible oil:\textsuperscript{1}:-

- 3-MCPDEs (< 1.25 ppm for soft oil and 2.5 ppm for palm oil)
- GEs (< 1 ppm)

European Food Safety Authority (EFSA) proposed Tolerable Daily Intake (TDI) limit of 0.8 μg/kg body weight for 3-MCPDE\textsuperscript{1}.
How can we mitigate this issue at palm oil mill?
3-MCPDE & GE
FORMATION & FACTORS
* a macroscopic perspective

- Formation
- Factors
3-MCPDE & GE Formation & Factors

**Formation**

- Only presence in refined oil and **not presence** in CPO$^4$.
- Formed during the CPO refining process at temperature of more than 200$^\circ$C - deodorisation process$^5$.
- 3-MCPDE & GE formation – through oils as DAG or MAG via acyloxonium ions as intermediates in presence of heat$^6,7$.
- 3-MCPDE formation – **with** present of chlorine.
- GE formation – **without** present of chlorine.
3-MCPDE & GE Formation & Factors

Factors

3-MCPDE\(^{6,8,9,10}\)
- Precursor: Chlorine, TAG, DAG, MAG
- Temperature
- Heating Time
- FFA, pH?

GE\(^{5,11,12,13}\)
- Precursor: DAG, MAG
- Temperature
- Heating Time
3-MCPDE & GE Formation & Factors

3-MCPDE Factors

Correlation of 3-MCPDE and Chlorine content

\[ R^2 = 0.7303 \]
• Sphingolipid organochlorine content in palm oil during palm oil milling process
3-MCPDE & GE Formation & Factors

3-MCDPE Factors

- Total Chlorine and 3-MCPD content in CPO and its refined oil respectively for types of dilution water used.
DAG formed during oil hydrolysis releasing FFA with the presence of water.

Hydrolysis reaction of vegetable oil$^{16}$
3-MCPDE & GE Formation & Factors

GE Factors

**Enzymatic Hydrolysis**

Due to:
- Presence of lipase enzymes on fruit surface.
  - Release when the fruits are bruised.
- Presence of lipolytic micro-organism.
- Need Moisture and Temperature
  - Lipase enzymes are inactivated at temperature of above 50°C.

Before heat treatment (sterilisation)

**Autocatalytic Hydrolysis**

Depends on:
- Moisture Content.
  - VM high-FFA high.
- Initial FFA.
  - High FFA content-Faster FFA formation.
- Temperature.
  - Storage Tank, Temp high-FFA high.
- Time/Period of Oil Storage.
  - Long time-FFA high.

Before & after heat treatment (sterilisation)

• Controlling the CPO FFA, controls the level of DAG
MITIGATION STRATEGIES

- Reduction of 3-MCPDE Precursor
- Improvement of Oil Quality
Mitigation Strategies

Possible Solution

Root Causes

CI
DAG
FFA?
Mitigation Strategies

Chlorine Mitigation

Reduction of Cl in CPO
- CPO Dechlorination
- CPO Washing

Reduction of Cl source
- Fruit Cleaning
- EFB/SC Oil Segregation
<table>
<thead>
<tr>
<th>Initiatives</th>
<th>Description</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Palm fruits cleaning</strong></td>
<td>• Dry &amp; wet cleaning system.</td>
<td>• High removal of trash content.</td>
<td>• High CAPEX.</td>
</tr>
<tr>
<td></td>
<td>• Removing the precursors sources of 3-MCPDE.</td>
<td>• Reduction in TC up to 30%.</td>
<td>• High maintenance cost.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduction of FFA by 40%</td>
<td>• High water usage.</td>
</tr>
<tr>
<td><strong>Secondary oil segregation</strong></td>
<td>• No restreaming of SC and EFB oil.</td>
<td>• Reduction of TC by 30%.</td>
<td>• High oil loss in waste stream.</td>
</tr>
<tr>
<td></td>
<td>• Main product – Clean CPO</td>
<td>• Clean CPO with better oil quality and stability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Secondary product - TGO</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CPO washing</strong></td>
<td>• Water washing of CPO.</td>
<td>• Reduction in TC up to 80%.</td>
<td>• High CAPEX.</td>
</tr>
<tr>
<td></td>
<td>• Before vacuum dryer.</td>
<td></td>
<td>• Additional wastewater.</td>
</tr>
<tr>
<td></td>
<td>• Pilot/ commercial scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CPO Dechlorination</strong></td>
<td>• Application of sodium metabisulfite (SMBS).</td>
<td>• Reduction in TC up to below 2 ppm.</td>
<td>• High SMBS cost</td>
</tr>
<tr>
<td></td>
<td>• Followed by filtration.</td>
<td></td>
<td>• Oil loss in spent SMBS.</td>
</tr>
</tbody>
</table>
How does improving the oil quality help to mitigate 3-MCPDE & GE?
Mitigation Strategies

Improvement of Oil Quality

- Improve Quality
- Reduce FFA
  - Reduce DAG Formation
  - Reduce Oil pH

Formation factors
Mitigation Strategies
Improvement of Oil Quality

- DAG, FFA
- TAG Degradation
- Enzymatic
  - Fruits Handling
  - Harvesting Interval
  - Fruits Freshness
- Autocatalytic
- Processing Condition
  - Processing Time
  - Oil Segregation
  - Moisture Content

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## Mitigation Strategies
### Improvement of Oil Quality

<table>
<thead>
<tr>
<th>Sample type</th>
<th>CPO (n =60)</th>
<th>RBDPO (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FFA</td>
<td>TC</td>
</tr>
<tr>
<td>Standard CPO</td>
<td>&lt;5%</td>
<td>4.06</td>
</tr>
<tr>
<td></td>
<td>(1.13-6.02)</td>
<td>(2.16-4.39)</td>
</tr>
<tr>
<td>Superior CPO</td>
<td>&lt;1.5%</td>
<td>2.11</td>
</tr>
<tr>
<td></td>
<td>(0.99-2.72)</td>
<td>(1.05-2.84)</td>
</tr>
<tr>
<td>Premium CPO</td>
<td>&lt;1.2%</td>
<td>1.77</td>
</tr>
<tr>
<td></td>
<td>(0.71-2.02)</td>
<td>(0.48-1.85)</td>
</tr>
</tbody>
</table>

- The above data was collected based on commercial physical refining route.
- Lower contaminants were observed through chemical refining route.
Mitigation Strategies

**Improvement of Oil Quality**

1. Optimise HI
2. Reduce Handling
3. Minimise Trash content
4. Fast evacuation

1. No secondary oil recovery
2. Immediate processing
3. Minimise CPO in storage tank

1. Refinery process modification
Conclusion

01. 3-MCPDE & GE only form in refinery at high heat. Not presence in CPO.

02. Precursors for are 3-MCPDE Cl & DAG, while GE is DAG.

03. Mitigation is proposed to start from estate an mill followed by refining process improvement.

04. Collective effort from planter, miller and refiner to mitigate this process contamination issue.
References


THANK YOU

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