Formation of 3-MCPD esters and Glycidyl esters during food preparation - What happens during frying, baking and barbecuing?

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Outline

- Background information
- Formation of 3-MCPD and glycidyl ester during barbecuing, frying and deep-fat frying
- Influence of free fatty acids on the product quality during storage of potato crisps
- Summary
Temperatures necessary for different cooking methods

- **boiling, stewing**
- **frying**
- **braising**
- **baking**
- **barbecuing**
- **deep-fat frying**

Temperature of the medium [°C]

3-MCPD ester

glycidyl ester
Change of the core temperature during deep-fat frying

Source: Chr. Gertz, Maxfry

Fried product: raw potatoes, 500 * 10 * 10 mm

MRI – Working Group for Lipid Research
Symposium on MCPD esters and glycidyl esters, Berlin
June 20 - 21, 2017
Oils higher in glycidyl esters are more susceptible to degradation by high temperature

Glycidyl palmitate might be quickly decomposed to hydrocarbons, aldehydes and CO₂ besides polar compounds by heating, in comparison with tripalmitate.

Glycidyl ester present in vegetable oils and French fries could be thermally unstable and easily decomposed to aldehydes, hydrocarbons, and polar compounds including polymers.

Oils higher in glycidyl esters are more susceptible to degradation by high temperature.
Is the source of 3-MCPD- and glycidyl esters in fried food endogenous or exogenous?

Endogenous: 3-MCPD and glycidyl esters are formed during processing

Exogenous: 3-MCPD and glycidyl esters are derived from the raw material, no new formation during processing

- In the case of an endogenous source of 3-MCPD and glycidyl esters the producer has to optimize the processing.
- In the case of an exogenous source of 3-MCPD and glycidyl esters the producer is depending on the quality of the raw material.
Influence of processing on the content of 3-MCPD and glycidyl ester during barbecuing

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Influence of processing on the content of 3-MCPD and glycidyl ester during barbecuing

3-MCPD ester and related compounds [mg/kg]

- OM oil-containing marinade
- AM water-containing marinade
- U without salt
- S salt
- A aluminium tray
- NA without aluminium tray
- L lidded
- WL without lid

3-MCPD ester

charcoal gas barbacue electro barbacue

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Influence of processing on the content of 3-MCPD and glycidyl ester during barbecuing

- During barbecuing mainly glycidyl ester are formed, while the content of 3-MCPD esters is below 1 mg/kg extracted fat.
- Assuming about 15% fat the content of 3-MCPD and glycidyl ester is below 1 mg/kg consumable product.
- Barbecuing with charcoal results in the highest amounts of 3-MCPD and glycidyl ester.
- The use of oil-containing marinades results in higher contents of the esters.
- The effect of salt is not clear.
- The use of aluminium trays results in lower values.
- No effect of the lid was found.
Removal of chloride from biscuit formulations controls formation of 3-MCPD, 2-MCPD, and bound-MCPD.

Careful selection of the type of vegetable oil or shortening and testing for MCPD ester content prior to their use in baking.

Increasing level of free 3-MCPD with stabilised yeast according to increasing acidity of the starter dough.
Influence of temperature and frying oil on the content of 3-MCPD- und glycidyl ester
Influence of temperature and frying oil on the content of 3-MCPD- und glycidyl ester

<table>
<thead>
<tr>
<th></th>
<th>3-MCPD ester</th>
<th>Glycidyl ester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial frying fat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat from meat (200° C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat from meat (240° C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frying fat (200° C)</td>
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</tr>
</tbody>
</table>

Endogenous formation of 3-MCPD and glycidyl ester during frying with clarified butter and vegetable creme
Effect of deep-fat frying on 3-MCPD and glycidyl ester

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**The effect of raw materials on thermo-oxidative stability and glycidyl ester content of palm oil during frying**

Magda A Aniolowska* and Agnieszka M Kita

J Sci Food Agric 2016; 96: 2257–2264

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<table>
<thead>
<tr>
<th>Source</th>
<th>R. Weisshaar, CVUA Stuttgart (2008)</th>
</tr>
</thead>
</table>

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**Table 4. Changes in composition of glycidyl esters (GE) in palm oil used for frying different products**

<table>
<thead>
<tr>
<th>Fried product and age of oil (h)</th>
<th>C16:0-GE</th>
<th>C18:0-GE</th>
<th>C18:1-GE</th>
<th>C18:2-GE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh oil</td>
<td>14.83±0.03</td>
<td>1.00±0.01</td>
<td>16.84±0.07</td>
<td>3.20±0.10</td>
</tr>
<tr>
<td>Chips</td>
<td>11.72±0.01</td>
<td>0.80±0.01</td>
<td>12.50±0.01</td>
<td>2.53±0.05</td>
</tr>
<tr>
<td>8 h</td>
<td>3.84±0.11</td>
<td>0.41±0.00</td>
<td>6.38±0.01</td>
<td>1.53±0.06</td>
</tr>
<tr>
<td>24 h</td>
<td>1.87±0.01</td>
<td>ND</td>
<td>4.90±0.00</td>
<td>1.13±0.01</td>
</tr>
<tr>
<td>French fries</td>
<td>10.00±0.10</td>
<td>0.69±0.00</td>
<td>10.99±0.01</td>
<td>2.73±0.01</td>
</tr>
<tr>
<td>8 h</td>
<td>4.20±0.00</td>
<td>0.29±0.01</td>
<td>4.04±0.00</td>
<td>0.94±0.01</td>
</tr>
<tr>
<td>40 h</td>
<td>0.85±0.01</td>
<td>ND</td>
<td>1.42±0.00</td>
<td>0.48±0.01</td>
</tr>
<tr>
<td>Snacks</td>
<td>8 h</td>
<td>6.65±0.01</td>
<td>0.58±0.01</td>
<td>8.66±0.01</td>
</tr>
<tr>
<td>24 h</td>
<td>1.93±0.00</td>
<td>0.18±0.01</td>
<td>3.04±0.01</td>
<td>0.96±0.01</td>
</tr>
<tr>
<td>40 h</td>
<td>0.85±0.00</td>
<td>ND</td>
<td>0.94±0.00</td>
<td>0.19±0.00</td>
</tr>
</tbody>
</table>

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**NaCl in the product leads to increased formation of 3-MCPD ester. No glycidyl esters are formed.**

K. Toho, AOCS Annual Meeting 2014

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**No endogenous formation of 3-MPCD- and glycidyl esters during production of potato crisps with HOSO**

Arens Döpsch8 · Reinhard Maihofer9

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Effect of temperature and chloride on the formation of 3-MCPD and glycidyl esters during deep-fat frying of chicken breast meat

- Significant (p < 0.05) decrease in the 3-MCPD esters and glycidyl esters with the increasing of the frying duration.
- Significant (p < 0.05) increases in the 3-MCPD esters formed when the concentration of NaCl increased from 0 to 5%.
- Addition of NaCl caused decreases in the level of GE.

No formation of glycidyl esters, remarkable increase of 3-MCPD esters during frying of chicken.
Mitigation of exogenous 3-MCPD and glycidyl ester during food processing

Results show no endogenous formation of 3-MCPD and glycidyl ester in fried vegetable products, but increase in meat and fish products

Contamination of fried vegetable products mainly from exogenous sources

Possibilities of mitigation
Application of fats and oils with low contents of 3-MCPD and glycidyl ester

Is it possible to use refined vegetable oils with higher amounts of free fatty acids for the preparation of food without changing the food quality?

Source: I. Berg; Sime Darby

MRI – Working Group for Lipid Research Symposium on MCPD esters and glycidyl esters, Berlin June 20 - 21, 2017
Effect of refined palm oils with different amounts of free fatty acids on product quality of processed food

Five palm oils with different contents of free fatty acids:
0.02; 0.12; 0.21; 0.31 and 0.49 g/100 g

Potato crisps: Storage 6 month at room temperature

Parameters
Sensory evaluation
Peroxide value
Content of free fatty acids

<table>
<thead>
<tr>
<th>Parameters</th>
<th>0.02 %</th>
<th>0.12 %</th>
<th>0.21 %</th>
<th>0.31 %</th>
<th>0.49 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycidyl ester [mg/kg]</td>
<td>4.1</td>
<td>3.3</td>
<td>2.7</td>
<td>2.2</td>
<td>0.8</td>
</tr>
<tr>
<td>2-MCPD ester [mg/kg]</td>
<td>3.4</td>
<td>3.1</td>
<td>3.2</td>
<td>3.3</td>
<td>2.9</td>
</tr>
<tr>
<td>3-MCPD ester [mg/kg]</td>
<td>6.1</td>
<td>5.6</td>
<td>5.9</td>
<td>6.1</td>
<td>5.6</td>
</tr>
</tbody>
</table>

- No contaminants like pesticides, PAH, or aflatoxins
- Low levels of heavy metals

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Influence of palm oil quality on storage stability of palm oil

T = 60° C

Significant influence of free fatty acids on storage stability of palm oil during storage at 60° C
Influence of different contents of free fatty acids on the quality of potato crisps during storage

Peroxide value [meq O2/kg]

Storage time [months]

FFA=0.02  FFA=0.12  FFA=0.21  FFA=0.31  FFA=0.49

Sensory evaluation

Storage time [months]

FFA=0.02  FFA=0.12  FFA=0.21  FFA=0.31  FFA=0.49
Endogenous formation of glycidyl esters during barbecuing, depending on the conditions.

Endogenous formation of 3-MCPD and glycidyl ester during frying with clarified butter and vegetable cremes.

No endogenous formation of esters during frying of potato crisps, but increase of 3-MCPD esters in presence of chloride.

Higher amounts of 3-MCPD and glycidyl ester in fried vegetable products resulted from exogenous sources.

Formation of 3-MCPD esters during frying of meat or fish.

Content of free fatty acids negatively influences the sensory evaluation of the final product during storage.
Thank you for your attention

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