BACKGROUND


2. The United States of America, as Chair of the EWG, prepared the draft code of practice (COP), with the assistance of the European Union and Malaysia. The draft COP is provided in Appendix I. The list of countries and non-governmental organizations (NGOs) that joined the EWG can be found in Appendix III. Comments and information were received from the following member countries and observers in response to a November 9, 2017 request for comment on the first draft: Australia, Brazil, Canada, China, Germany, Japan, Malaysia, FEDIOL (the EU Vegetable Oil and Proteinmeal Industry), FoodDrinkEurope, GOED (Global Organization for EPA and DHA Omega-3s), ICGMA (International Council of Grocery Manufacturers Associations), IMACE (the European Margarine Association), ISDI (International Specialty Dietary Foods Industries), and SNE (Specialised Nutrition Europe).

REQUEST FOR COMMENTS

Codex members and observers are kindly invited to provide comments on the second draft of the COP in Appendix I.

Codex members and observers also are invited to provide input on the following comments regarding the title—Code of Practice for the Reduction of 3-Monochloropropane-1,2-diol Esters and Glycidyl Esters in Refined Oils and Products Made with Refined Oils, Especially Infant Formula—included in the CCCF/CAC approved project document:

- One country and two observers suggested removing the wording, “Especially Infant Formula” to eliminate confusion that this COP is applicable only to infant formula and to reflect that it applies to all products that use refined oils. On the other hand, the title may be appropriate given that formula is the primary source of exposure for infants to 3-MCPDE and GE, infants are the most sensitive population, and such wording does not detract from the recognition that the document addresses all products containing refined vegetable oils.
- One observer suggested clarifying the title by inserting the word “vegetable” so that it reads, Code of Practice for the Reduction of 3-Monochloropropane-1,2-diol Esters and Glycidyl Esters in Refined Vegetable Oils and Products Made with Refined Vegetable Oils, Especially Infant Formula.

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INTRODUCTION

1. Edible vegetable oils are produced from fruits, seeds, and nuts. Refining of edible vegetable oils (at temperatures of about 200°C or higher) can produce 3-monochloropropene-1,2-diol (MCPD) esters (3-MCPDE) and glycidyl esters (GE). Fruit oil has been reported to have the highest concentrations of these esters and the greatest consumption rate worldwide, in comparison to other refined seed oils (e.g., grapeseed, olive, soya bean, rapeseed, sunflower, walnut, hazelnut). 3-MCPDE and GE are broken down to their non-esterified forms, the toxicological data for which are available. 3-MCPDE and GE have toxic effects on the kidney and male reproductive organs, and 3-MCPD is a non-genotoxic carcinogen. Glycidol is a genotoxic carcinogen.

2. In 2016, at the request of the Codex Committee on Contaminants in Food (CCCF), the FAO/WHO Joint Expert Committee on Food Additives (JECFA) evaluated the toxicity of 3-MCPDE and GE and dietary exposure to these compounds. 3-MCPDE and 3-MCPD have toxic effects on the kidney and male reproductive organs, and 3-MCPD is a non-genotoxic carcinogen.

3. JECFA established a group provisional maximum tolerable daily intake (PMTDI) of 4 µg/kg bw for 3-MCPD and 3-MCPDE (singly or in combination, expressed as 3-MCPDE equivalents) based on renal tubular hyperplasia in male rats. JECFA noted that the estimated dietary exposures to 3-MCPD for the general population, even for high consumers, do not exceed the PMTDI. However, mean dietary exposures to 3-MCPD for formula-fed infants in some countries do exceed the PMTDI by 2.5 times. For GE, a genotoxic carcinogen, it is not appropriate to establish a health-based guidance value. Therefore, JECFA calculated margins of exposure (MOE) for GE (expressed as glycidol) ranging from 490 to 24,000 based on a benchmark dose lower limit (BMDL\text{10}) of 2.4 mg/kg bw/day for mesotheliomas in male rats. JECFA considered that lower ends of the ranges of the MOEs for infants, children, and adults may be a health concern, as they were less than 10,000.

4. Exposure to 3-MCPDE and GE can occur through consumption of refined edible oils and food products containing edible oils, including infant formula. JECFA recommended that efforts to reduce 3-MCPDE and 3-MCPD in infant formula be implemented and that measures to reduce GE and glycidol in fats and oils continue, particularly when used in infant formula.

5. 3-MCPDE and GE are found in products made from refined oils, for example, infant formula, potato products (e.g., french fries and potato crisps), and fine bakery wares (e.g., cookies, croissants, and

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4 Because toxicokinetic data indicate that 3-MCPDE and GE are broken down to their non-esterified forms, the toxicological assessments were based on 3-MCPD and glycidol (compounds for which toxicological data are available) (JECFA 2017).
Levels of 3-MCPDE and GE in foods made from refined oils correspond to the concentrations of 3-MCPDE and GE in the refined oils. Data suggest that the use of refined vegetable oils themselves during frying does not contribute to the formation of additional 3-MCPDE and GE, but rather the formation of additional 3-MCPDE and GE may result from the type of food that is fried.

6. Different types of unrefined vegetable oils have different capacities to form 3-MCPDE and GE during deodorization (part of the refining process). Factors contributing to this variation include climate, soil and growth conditions of the plants, their genotype, harvesting techniques, and processing conditions—all of which affect the levels of precursors of 3-MCPDE and GE (e.g., acrylglycerols, chlorine-containing compounds). Most unrefined oils do not contain detectable levels of 3-MCPDE or GE.

7. 3-MCPDE forms primarily from the reaction between chlorine containing compounds and acrylglycerols like triacylglycerols (TAGs) and diacylglycerols (DAGs). GE forms primarily from DAGs or monoaoylglycerols (MAGs).

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1. SGS Germany GmbH. 2016. Final scientific report on the decision support project. Investigation into the presence of 3-MCPDE esters and related compounds in foods. Ref.: 314-06.01-2815HS002.
3. EFSA 2016. Risks for human health related to the presence of 3- and 2-monochloropropanediol (MCPD), and their fatty acid esters, and glycidyl fatty acid esters in food. EFSA Journal. 14(5): 1-159.
4. SGS Germany GmbH. 2016. Final scientific report on the decision support project. Investigation into the presence of 3-MCPDE esters and related compounds in foods. Ref.: 314-06.01-2815HS002.
5. Food Additives.
6. SGS Germany GmbH. 2016. Final scientific report on the decision support project. Investigation into the presence of 3-MCPDE esters and related compounds in foods. Ref.: 314-06.01-2815HS002.
8. SGS Germany GmbH. 2016. Final scientific report on the decision support project. Investigation into the presence of 3-MCPDE esters and related compounds in foods. Ref.: 314-06.01-2815HS002.
8. Some chlorinated compounds are precursors for 3-MCPDE formation. Research studies in oil palm trees have shown that chloride ions (in the form of chlorinated compounds) are absorbed during tree growth from the soil (including from fertilizers and pesticides) and water, and are metabolized into hydrophobic chlorinated compounds that may generate hydrochloric acid during oil refining, leading to formation of 3-MCPDE.1

9. Oil seeds and fruits contain the enzyme lipase; lipase activity increases with fruit maturation and seed germination2. Lipase interacts with oil from matured fruits or seeds to rapidly degrade triacylglycerols into free fatty acids (FFAs) and DAGs and MAGs.3-4

10. GE formation begins at about >200°C, and increases exponentially with increasing temperature when DAGs exceed 3-4% of total lipids5, while 3-MCPDE formation occurs at temperatures as low as 160-200°C, and formation does not increase with higher temperatures.5,7-8

11. Indirect and direct analytical methods are used to determine levels of 3-MCPDE and GE concentrations in refined oils and in foods made from refined oils.5 Indirect methods require hydrolytic cleavage of the fatty acid esters from the glycidol (before or after reaction with bromide) or 3-MCPD component prior to analysis, while for direct methods, analysis is conducted on intact 3-MCPDE or GE.9 The AOCS (American Oil Chemists' Society) has established three inter-laboratory, validated (indirect) methods for determining 3-MCPDE and GE in edible oils and fats.11 Few methods, whether indirect or direct, have been validated for use in complex foods.

12. Because 3-MCPDE and GE are formed via different mechanisms, different mitigation strategies are needed to control their formation. Because of the different formation mechanisms, there generally is not a relationship between relative levels of 3-MCPDE and GE in individual oil samples.10

13. GE is generally easier to mitigate than 3-MCPDE, because its formation is directly associated with elevated temperatures (with formation beginning at about 200°C, and becoming more significant at temperatures >230°C). GE is formed primarily from DAGs, and does not require the presence of chlorinated compounds. Oils can be deodorized at temperatures below 230°C to avoid significant GE formation.

Comment [MFZ2]: This statement is not substantiated with the current opinion.

formation. However, it is not practical to decrease deodorization temperatures below the threshold that would lead to 3-MCPDE formation, as that could affect the quality and safety of the oil.\textsuperscript{1,2}

14. Although 3-MCPDE and GE are primarily produced during deodorization, mitigation measures can be applied across the edible oil production chain beginning with agricultural practices (e.g., cultivation, harvesting and storage of fruits and seeds) to oil milling and refining (e.g., fruit and seed selection and processing, degumming/bleaching, and deodorization) as well as post-refining measures (e.g., use of adsorbants, cation-exchange resin, enzymes).

15. Various organizations, including BLL (German Federation for Food Law and Food Science) and FEDIOL (European Union Vegetable Oil and Proteinmeal Industry), have developed guidance on mitigating 3-MCPDE and GE in refined oils and in foods containing refined oils.\textsuperscript{3-6}

16. Although most work on mitigation of 3-MCPDE and GE in refined oils has focused on palm oil because of its greater capacity to form 3-MCPDE and GE and its importance economically, some of the information and experience on mitigation of 3-MCPDE and GE in palm oil may be applicable to mitigation of 3-MCPDE and GE in other refined oils.\textsuperscript{6} Therefore, where data are available, this document specifies when the mitigation approach is specific to palm oil, and when it may be more widely applicable to other vegetable oils.

17. There are a wide range of methods to mitigate 3-MCPDE and GE, and the applicable methods used will vary depending on different conditions (including the oilseed or fruit being processed, the refining process, and the type of equipment installed). In addition, multiple methods may need to be combined to reduce 3-MCPDE and GE in oils. This document discusses both methods currently in use by industry and those that are still in their experimental stages, as the methods applied will vary among and within industries. New methods will need to be tested at the industrial scale to assess their practicality and validity.

18. Although this document does not address 2-MCPDE, as there are little data available, it is likely that mitigation of 3-MCPDE may lead to reduction of 2-MCPDE.\textsuperscript{7,8}

19. Knowing what precursors are present in batches of crude vegetable oils may allow one to adjust refining parameters and to target appropriate mitigation strategies.\textsuperscript{9} Where possible, it may be best to remove precursors at the earlier stages of processing, to minimize the formation of 3-MCPDE and GE.\textsuperscript{10} For example, efforts to mitigate 3-MCPDE should also focus on cultivation, harvesting, and milling, not just refining.


\textsuperscript{4} BLL 2016. Toolbox for the mitigation of 3-MCPD esters and glycidyl esters in food. February 2016.

\textsuperscript{5} In 2008, Codex established a Code of Practice (CAC/RCP 64-2008) and a Maximum Level (CODEX STAND 193-1995) for 3-MCPD in acid-hydrolyzed vegetable proteins. (This COP does not address mitigation measures for 3-MCPD.)


\textsuperscript{7} BLL 2016. Toolbox for the mitigation of 3-MCPD esters and glycidyl esters in food. February 2016.

\textsuperscript{8} Ermacora A. and Hinrichsen K. 2014. Influence of oil composition on the formation of fatty acid esters of 2-chloropropane-1,3-diol (2-MCPD) and 3-chloropropane-1,2-diol (3-MCPD) under conditions simulating oil refining. Food Chemistry. 383-389.


\textsuperscript{10} Matthäus, B. and Pudel F. 2013. Mitigation of 3-MCPD and glycidyl esters within the production chain of vegetable oils especially palm oil. Lipid Technol. 25(7): 151-155.
20. Care should be taken so as not to mitigate 3-MCPDE at the expense of GE, or vice versa.1

21. In concert with mitigation of 3-MCPDE and GE, it is important to also consider the overall impacts on the quality of refined oils and oil-based products including product properties—smell and taste, stability, levels of nutrients and removal of contaminants such as pesticides and mycotoxins.2 In addition, environmental impacts of the recommended mitigation practices should be considered.

RECOMMENDED PRACTICES BASED ON GOOD AGRICULTURAL PRACTICES (GAP) AND GOOD MANUFACTURING PRACTICES (GMP)

22. Producing edible oils involves several major steps: cultivating, harvesting, and transporting the fruits and seeds for further processing; oil milling where palm fruit is sterilized, while oilseeds are cleaned, ground, and steamed; extracting oil from the fruits and seeds; and refining.

23. Refining consists of two main types; chemical or physical refining. Chemical refining consists of degumming (removal of phospholipids); neutralization (addition of hydroxide solution to remove free fatty acids (FFA) through formation of soaps); bleaching (using clays) to reduce colors and remove remaining soaps and gums, trace metals, and degradation products; and deodorization (i.e., a steam-distillation process carried out at low pressures, 1.5-6.0 mbar, and elevated temperatures, 180-270°C) to remove FFA, colors, and volatile compounds. Physical refining involves degumming, bleaching, and deodorization combined with decolorization, but does not have a neutralization step. While several factors influence the selection of physical refining3, it is typically conducted on oils containing low levels of phospholipids.

AGRICULTURAL PRACTICES

24. Consider selecting oil plant varieties with low lipase activity (e.g., for palm oil, <10 µmol fatty acid released per minute/gram dry mesocarp) to reduce formation of FFA and glyceryl precursors.4

25. Minimize use of substances such as fertilizers, pesticides, and irrigation water that have excessive amounts of chlorine-containing compounds during cultivation to reduce chlorine absorption by the oil trees and ultimately the palm fruits. For oil palm trees, avoid cultivation on saline soils.5

26. Harvest oil palm fruit when they are at optimal ripeness. Minimize handling of the fresh fruit bunches to reduce bruising and prevent formation of FFA.6 Avoid using damaged or overripe fruits, which may be associated with higher 3-MCPDE and GE formation.7

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27. Transport oil palm fruits to oil mills as soon as possible.

**OIL MILLING AND REFINING**

**Crude Oil Production and Treatment**

28. Following receipt of the oil palm fruits at the mill, sterilize the fruits immediately (preferably within a few hours to less than 2 days) at temperatures at or below 120°C to inactivate lipases.\(^5\),\(^8\),\(^9\)

29. Wash crude vegetable oil with polar solvents like chlorine-free water or water/alcohol (ethanol) mixture to remove chlorine-containing compounds. Experimentally, washing palm fruit pulp during oil extraction with organic solvent (e.g., hexane:water [2:1 volume/volume] or isopropanol) also has been shown to remove chlorine.\(^6\),\(^7\),\(^8\),\(^9\)

30. Avoid recycling residual oil recovered from solvents or additional extractions, as this oil tends to have higher levels of precursors (e.g., chlorine-containing compounds, DAGs).\(^10\),\(^11\)

31. Assess precursors in batches of crude vegetable oils (e.g., DAGs, chlorine-containing compounds) to adjust refining parameters and target appropriate mitigation strategies depending on the type of vegetable oil being processed and processing conditions.\(^12\)

32. Preferentially refining crude vegetable oil with low concentrations of precursors can produce finished oils with lower levels of 3-MCPDE and GE. For example, refining crude palm oil with <4% DAG and <2.5% FFA or <5.5% DAG and <1.5% FFA has been shown under experimental conditions to reduce formation of GE, as the level of DAG has a positive correlation with the level of FFA.\(^13\),\(^14\),\(^15\)

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5. Stadler et al. 2015. Monochloropropene-1,2-diol esters (MCPDEs) and glycidyl esters (GEs): an update. Current Opinion in Food Science. 6:12-18.
Degumming

33. During wet degumming, increasing the amount of water under experimental conditions removes 3-MCPDE precursors in palm oil.5

34. Use milder and less acidic conditions (e.g., either degumming with a low concentration of phosphoric acid (0.02%) or water degumming) to decrease 3-MCPDE in vegetable oils.7 The concentration of phosphoric acid needed depends on the quality of the crude vegetable oil. Care should be taken to remove sufficient concentrations of phospholipids and phosphoric acid to ensure quality.

35. Lowering the degumming temperature may help to reduce formation of 3-MCPDE precursors in vegetable oils4, however, the degumming temperature will depend on numerous factors including type of vegetable oil.

Neutralization

36. Using chemical refining (i.e., neutralization) in place of physical refining can help remove precursors (e.g. chloride) and may allow for lower deodorization temperatures in vegetable oils. However, chemical refining can lead to excessive oil loss (especially for palm oil due to higher FFA levels), and may have a greater environmental impact than physical refining.7

37. Neutralization with calcium oxide prior to deodorization of palm oil may reduce acidic conditions and help remove precursors.5 Addition of alkaline carbonates or hydrogen carbonates in sunflower oil (i.e., K2CO3 and Na2CO3 or KHCO3 and NaHCO3) before deodorization has also been shown experimentally in the laboratory to neutralize fatty acids (and possibly chloride).7

Bleaching

38. Use of greater amounts of bleaching clay may reduce formation of 3-MCPDE and GE in all vegetable oils.8,9 However, bleaching clays that contain significant amounts of chlorine-containing compounds should be avoided.

39. Use of more pH-neutral clays reduces the acidity, and the number of reactions of acylglycerols with chloride to form 3-MCPDE in palm oil and some seed oils.10

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Deodorization

40. Consider conducting deodorization of vegetable oils at reduced temperatures to decrease formation of GE. For example, it has been suggested to conduct deodorization at 190-230°C.1

41. As an alternative to traditional deodorization, conduct dual deodorization of vegetable oils (2-stage deodorization) to reduce thermal load in oil. This includes both a shorter (e.g., 5 minutes at 250°C) and a longer (e.g., 120 minutes at 200°C) deodorization period.2 However, consideration needs to be given to parameters such as temperature, vacuum pressure, and time, and variations in equipment design and capability.

42. Use of a stronger vacuum facilitates evaporation of volatile compounds due to the increased steam volume and rate of stripping, contributing to decreased deodorization temperatures and reduced formation of 3-MCPDE and GE in vegetable oils.3,4

43. Short-path distillation5 (in place of deodorization) has been shown experimentally in palm oil to reduce the thermal load and formation of esters, contributing to lower amounts of 3-MCPDE and GE in comparison to conventional deodorization. However, additional post processing using mild deodorization (i.e., 160-180°C) is needed to address sensory considerations, and the resulting palm oil will be red in color due to carotenoids.6

44. Use of antioxidants, such as tert-butyl hydroquinone (THBQ), propyl gallate (PG), and L-ascorbyl palmitate (AP), has been shown experimentally to reduce formation of 3-MCPDE in rapeseed oil during heating.7

TREATMENT POST REFINING

45. Use of adsorbents, including calcinated zeolite and synthetic magnesium silicate, following deodorization of palm oil, has been experimentally shown to remove GE.9

46. Conduct additional bleaching and deodorization steps following initial bleaching and deodorization of the refined palm oil, to achieve lower levels of GE in the refined palm oil. (The second deodorization should occur at a lower temperature than the first deodorization.)10

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2 Matthäus B. and Pudel F. 2013. Mitigation of 3-MCPD and glycidyl esters within the production chain of vegetable oils especially palm oil.
5 Short-path distillation enables gentle removal of volatile compounds at relatively low temperatures. This is accomplished through reduced pressure, where the boiling point of the compound to be separated is lowered and there is increased efficiency due to the short distance between the evaporator and the condenser surface (Pudel et al. 2016).
47. Application of activated bleaching earth has been shown experimentally to convert GE in refined vegetable oils to MAGs and DAGs.1

48. Conducting post-treatment of refined vegetable oils with carboxymethyl cellulose or cation-exchange resin in combination with a nitrogen treatment has been shown experimentally to reduce 3-MCPDE.2

49. Use of short-path distillation (pressure: <1 mbar and temperature: 120 to 270°C) on bleached and deodorized vegetable oils can reduce acylglycerol components and levels of 3-MCPDE and GE.3

50. Enzymes (a combination of halohydin dehalogenase and epoxide hydrolase) have been shown experimentally to mitigate 3-MCPDE in refined palm oil through conversion to glycerol.4

51. Treatment of refined MCT (medium-chain triglyceride) oil with one or more bases (including carbonate, bicarbonate, hydroxide, oxide, alkoxide, amine bases, hydrides, and phosphines) converts 3-MCPDE and GE to triglycerides.5 This method is being tested using other vegetable oils.

SELECTION AND USES OF REFINED OILS IN PRODUCTS MADE FROM THESE OILS, ESPECIALLY INFANT FORMULA

Oil selection

52. Selecting refined vegetable oils with lower levels of 3-MCPDE and GE (e.g., either through natural occurrence or through application of mitigation measures) can produce lower levels of 3-MCPDE and GE in finished products containing these oils.6,7,8,9,10 For example, variation in levels of 3-MCPDE and GE in infant formula has been observed, which may be due to the types of oils selected.11,12 However, in some cases, it may be difficult to replace particular oils in the finished products due to desired quality or compositional factors. For example, for infant formula, refined oils are selected by manufacturers to ensure these products meet national compositional criteria established in the Codex Infant Formula Standard (CODEX STAN 72-1981).

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Comment [AE12]: Is this mitigation method used in practice, or is it just experimental?

Comment [MFZ13]: The enzymes are not available commercially. Hence, it will be difficult to be used to remove 3-MCPDE. This statement is not relevant.

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7 SGS Germany GmbH. 2016. Final scientific report on the decision support project. Investigation into the presence of 3-MCPD esters and related compounds in foods. Ref: 314-06.01-2815HS002.
8 EFSA 2016. Risks for human health related to the presence of 3- and 2-monochloropropanediol (MCPD), and their fatty acid esters, and glycidyl fatty acid esters in food. EFSA Journal. 14(5): 1-159.
12 EFSA 2016. Risks for human health related to the presence of 3- and 2-monochloropropanediol (MCPD), and their fatty acid esters, and glycidyl fatty acid esters in food. EFSA Journal. 14(5): 1-159.
Processing modifications

53. Reducing the amount of refined vegetable oils in finished products is expected to reduce the levels of 3-MCPDE and GE in the finished product. However, this could impact the organoleptic or nutritional qualities of the finished products.

54. Use of refined vegetable oils themselves during frying does not contribute to formation of additional 3-MCPDE and GE, but rather the formation of additional 3-MCPDE and GE during frying may result from the type of food that is fried. 1,2,3,4,5,6,7

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2 SGS Germany GmbH. 2016. Final scientific report on the decision support project. Investigation into the presence of 3-MCPD esters and related compounds in foods. Ref.: 314-06.01-2815HS002.
APPENDIX II

POTENTIAL MITIGATION MEASURES FOR REDUCING 3-MCPDE AND GE

It is recommended that all reduction measures be tested to identify the most successful for your own product.

<table>
<thead>
<tr>
<th>Production Stage</th>
<th>Mitigation measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGRICULTURAL PRACTICES</td>
<td>Select oil plant varieties with low lipase activity.</td>
</tr>
<tr>
<td></td>
<td>Minimize use of substances such as fertilizers, pesticides, and irrigation water that contain excessive amounts of chlorine during oil palm cultivation. For oil palm trees, avoid cultivation on saline soil.</td>
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<td>Harvest oil palm fruits when they are at optimal ripeness. Minimize handling of fresh fruit bunches. Avoid using damaged or overripe fruit.</td>
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<td></td>
<td>Transport oil palm fruits to oil mills as soon as possible.</td>
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<tr>
<td>CRUDE OIL PRODUCTION AND TREATMENT</td>
<td>Sterilize oil palm fruits at temperatures at or below 120°C.</td>
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<td></td>
<td>Wash crude vegetable oil with polar solvents (e.g., chlorine-free water or water/alcohol mixtures).</td>
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<td></td>
<td>Avoid recycling residual oil recovered from solvents or extractions.</td>
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<tr>
<td></td>
<td>Assess precursors (e.g., DAGs and chlorine compounds) in batches of crude vegetable oil to adjust refining parameters.</td>
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<td></td>
<td>Preferentially refine crude vegetable oil with low concentrations of precursors.</td>
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<tr>
<td>Degumming</td>
<td>During wet degumming, increase the amount of water used.</td>
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<tr>
<td></td>
<td>Use milder and less acidic conditions, e.g., either degumming with a low concentration of phosphoric acid (0.02%) or water degumming for vegetable oils.</td>
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<tr>
<td></td>
<td>Lowering the degumming temperature may reduce formation of 3-MCPDE precursors in vegetable oils.</td>
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<tr>
<td>Neutralization</td>
<td>Use of chemical refining (i.e., neutralization) in place of physical refining can help remove precursors (e.g., chloride) and may allow for lower deodorization temperatures in some vegetable oils.</td>
</tr>
<tr>
<td></td>
<td>Neutralization of palm oil with calcium oxide may reduce acidic conditions and help remove precursors.</td>
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<tr>
<td>Bleaching</td>
<td>Use greater amounts of bleaching clay in vegetable oils.</td>
</tr>
<tr>
<td></td>
<td>Use more pH-neutral clays to reduce acidity in palm oils and some seed oils.</td>
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**POTENTIAL MITIGATION MEASURES FOR REDUCING 3-MCPDE AND GE**

It is recommended that all reduction measures be tested to identify the most successful for your own product.

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<td>Consider conducting deodorization of vegetable oils at reduced temperatures.</td>
<td></td>
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<tr>
<td>An alternative to traditional deodorization is dual deodorization (2-stage deodorization) of vegetable oils which includes a shorter (e.g., 5 minutes at 250°C) and a longer (e.g., 120 minutes at 200°C) deodorization period.</td>
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<tr>
<td>Use of a stronger vacuum facilitates evaporation of volatile compounds and contributes to decreased deodorization temperatures in vegetable oils.</td>
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<td><strong>TREATMENT POST REFINING</strong></td>
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<tr>
<td>Use adsorbents, including calcinated zeolite and synthetic magnesium silicate in palm oil, to remove GE.</td>
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<td>Conduct additional bleaching and deodorization following initial bleaching and deodorization of refined palm oil.</td>
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<tr>
<td>Application of activated bleaching clay to refined vegetable oils has been shown experimentally to can convert GE to MAGs and DAGs.</td>
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<tr>
<td>Treatment of refined vegetable oils with carboxymethyl cellulose or cation-exchange resin in combination with a nitrogen treatment.</td>
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<tr>
<td>Use short-path distillation on bleached and deodorized vegetable oils.</td>
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<td>Treatment of refined MCT (medium-chain triglyceride) oil with bases converts 3-MCPDE and GE to triglycerides.</td>
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<tr>
<td><strong>OIL SELECTION</strong></td>
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<tr>
<td>Selecting refined vegetable oils with lower levels of 3-MCPDE and GE can result in lower levels of 3-MCPDE and GE in the finished product.</td>
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<tr>
<td><strong>PROCESS MODIFICATIONS</strong></td>
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<tr>
<td>Reducing the amount of refined vegetable oils in finished products may reduce the levels 3-MCPDE and GE in finished products.</td>
<td></td>
</tr>
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<td>Using refined vegetable oils themselves in frying does not contribute to the formation of additional 3-MCPDE and GE, but rather the formation of additional 3-MCPDE and GE may result from the type of food that is fried.</td>
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APPENDIX III
LIST OF PARTICIPANTS

CHAIR United States
Eileen Abt
U.S. Food and Drug Administration
Center for Food Safety and Applied Nutrition
eileen.abt@fda.hhs.gov

CO-CHAIR European Union
Frans Verstraete
European Commission
frans.verstraete@ec.europa.eu

CO-CHAIR Malaysia
Rosidah Radzian
Malaysian Palm Oil Board
rosidah@mpob.gov.my

Argentina
Lic. Silvana Ruarte
Dirección de Fiscalización, Vigilancia y Gestión de Riesgo
Instituto Nacional de Alimentos
sruarte@anmat.gov.ar
codex@magp.gob.ar

Austria
Kristina Marchart
Austrian Agency for Health and Food Safety
Kristina.marchart@ages.at

Australia
Matthew O’Mullane
Food Standards Australia New Zealand
Mathew.O’Mullane@foodstandards.gov.au

Bulgaria
Svetlana Tcherkezova
Ministry of Agriculture, Food and Forestry

Belgium
Korati Safia
Regulatory Expert
Federal Public Service Health Food Safety
Safia.korati@sante.belgium.be

Brazil
Lígia Lindner Schreiner
Expert on Regulation and Health Surveillance
Brazilian Health Regulatory Agency - ANVISA
ligia.schreiner@anvisa.gov.br

Canada
Luc Pelletier
Scientific Evaluator, Food Contaminants Section
Bureau of Chemical Safety
Health Canada
luc.pelletier@hc-sc.gc.ca

China
Mr. Yongning WU
Professor, Chief Scientist
China National Center of Food Safety Risk Assessment (CFSA)
wuyongning@cfsa.net.cn

Ms. Hong Miao
Researcher
China National Center of Food Safety Risk Assessment (CFSA)
shaoy@cfsa.net.cn

Mr. Jinguang Li
Researcher
China National Center for Food Safety Risk Assessment (CFSA)
lijg@cfsa.net.cn

Mr. Zhiyong GONG
Professor
College of Food Science and Engineering, Wuhan Polytechnic University, CHINA
gongzycn@whpu.edu.cn

Wang Songxue
wsx@chinagrain.org

Dominican Republic
Fatima del Rosario Cabrera
General Directorate of Medicines, Food and Health Products Ministry of Public Health and Social Assistance
codex.pccolor@msp.gob.do

Egypt
Noha Mohamed Atia
Egyptian Organization for Standardization and Quality

European Union
Frans Verstraete
European Commission
Director General for Health and Consumers
frans.verstraete@ec.europa.eu

Germany
Dr. Annette Rexroth
Senior Officer
Federal Ministry for Nutrition and Agriculture
Annette.Rexroth@bmel.bund.de

India
Mr. Sunil Bakshi
Food Safety and Standards Authority of India
s.bakshi@fssai.gov.in

Ms. Dicksha Mathur
Regulatory Advocacy
Nestle India Ltd.
dicksha.mathur@in.nestle.com

Mr. Kannan B
Assistant Manager
ITC Limited
Kannan.B@itc.in

Dr. R.B.N. Prasad
Chairman
Oils & Fats Panel, FSSAI
rbnprasad@gmail.com

Indonesia
Tegy Usia
Director of Food Product Standardization
National Agency of Drug and Food Control
codexpom@gmail.com

Japan
Dr. Yukiko Yamada

Advisor to Vice-Minister
Ministry of Agriculture, Forestry and Fisheries of Japan
yukiko_yamada530@maff.go.jp

Mr. Yoshiyuki TAKAGISHI
Associate Director
Food Safety Policy Division, Food Safety and Consumer Affairs Bureau, Ministry of Agriculture, Forestry and Fisheries of Japan
yoshiyuki_takagis500@maff.go.jp

Korea
Min Yoo
Codex Researcher
Ministry of Food and Drug Safety
minyoo83@korea.kr
Codexkorea@korea.kr

Malaysia
Rosidah Radzian
Malaysian Palm Oil Board
rosidah@mpob.gov.my

Raznim Arni Abd Razak
Malaysian Palm Oil Board
raznim@mpob.gov.my

Raizawanis Abdul Rahman
raizawanis@moh.gov.my

New Zealand
John Reeve
Principle Adviser Toxicology
Ministry for Primary Industries
john.reeve@mpi.govt.nz

Russian Federation
Irina Sedova
Federal Research Centre of Nutrition and Biotechnology

Spain
Marta Perez Gonzalez
Technical expert
Contaminants Management Department
Sub-directorate-General for Food Safety Promotion
Spanish Agency for Consumer Affairs, Food Safety and Nutrition
contaminantes@msssi.es

Switzerland
Ms. Lucia Klauser
Scientific Officer
Federal Food Safety and Veterinary Office
lucia.klauser@blv.admin.ch

Thailand
Mrs. Chutlwan Jatupornpong
Standards Officer, Office of Standards Development National Bureau of Agricultural Commodity and Food Standards
chutlwan9@hotmail.com

Turkey
Betül VAZGEÇER
United States of America
Eileen Abt
U.S. Food and Drug Administration
Center for Food Safety and Applied Nutrition
eileen.abt@fda.hhs.gov

Henry Kim
U.S. Food and Drug Administration
Center for Food Safety and Applied Nutrition
henry.kim@fda.hhs.gov

Shaun MacMahon
U.S. Food and Drug Administration
Center for Food Safety and Applied Nutrition
shaun.macmahon@fda.hhs.gov

Paul South
U.S. Food and Drug Administration
Center for Food Safety and Applied Nutrition
paul.south@fda.hhs.gov

FAO (JECFA)
Dr. Markus Lipp
Senior Officer
Agriculture and Consumer Protection Department
Food and Agriculture Organization of the UN
Viale delle Terme di Caracalla
markus.lipp@fao.org

Dr. Vittorio Fattori
Food Safety Officer

Agriculture and Consumer Protection Department
Food and Agriculture Organization of the UN
Viale delle Terme di Caracalla
vittorio.fattori@fao.org

FEDIOL
Kalila Hajjar
Senior Manager, Scientific and Regulatory Affairs
khajjar@fediol.eu

FoodDrinkEurope
Eoin Keane
Manager Food Policy, Science and R&D
e.keane@fooddrinkeurope.eu

Global Organization for EPA and DHA Omega-3s (GOED)
Gerard Bannenberg
Director of Compliance and Scientific Outreach
gerard@goedomega3.com

IFFO (The Marine Ingredients Organisation)
Dr. Gretel Bescoby
Technical Manager
gbescoby@iffo.net

IMACE (Margarine Producers in Europe)
Siska Pottie
SPottie@Imace.org

International Council of Grocery Manufacturers Associations (ICGMA)
René Viñas
Lead Delegate
International Council of Grocery Manufacturers
Associations (ICGMA)
rvinas@gmaonline.org

International Special Dietary Foods Industries (ISDI)
Jean Christophe Kremer
Secretary General
secretariat@isdi.org

Specialised Nutrition Europe
Paul Hanlon
Toxicologist and Regulatory Affairs Director
paul.hanlon@abbott.com