Code of Practice for Reduction of 3-MCPD Esters and Glycidyl Esters by Codex: Are We Ready to Adopt?

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INTRODUCTION

The 3-monochloropropanediol esters (3-MCPDE) and glycidyl esters (GE) are processed food contaminants formed when vegetable oil is heated to 180°C (Hrncirik and van Duijin, 2011). The precursors are chlorine or chloride for the former and diacylglycerol for the latter (Destaillats, 2012a and 2012b). When consumed, 3-MCPDE will be hydrolysed to 3-MCPD whilst GE to glycidol in the gastrointestinal tract (JECFA, 2016). Both hydrolysed products are reported to be potentially carcinogenic to human (IARC Monographs, 2000 and 2012). A study by European Food Safety Authority (EFSA, 2018) concluded that 3-MCPDE could induce reduced sperm mortility and kidney tubular hyperplasia.

The Codex Alimentarius (Codex), or 'Food Code' is a collection of internationally recognised standards, guidelines and codes of practice adopted by the Codex Alimentarius Commission (FAO, 2020). The Codex Alimentarius is recognised by the World Trade Organization as international reference point for the resolution of disputes concerning food safety and consumer protection. Due to the harmful effects of the 3-MCPDE and GE, Codex has established a code of practice (CoP) for reducing the formation of the contaminants in refined oils, which is applicable to all oils and fats (Codex, 2019). The recommendations are shown in *Tables 1* and *2*. The CoP covers three strategies, namely, good agricultural practices, good manufacturing practices, and selection and uses of refined oils in food products.

Sectors that are covered under the agricultural practices are cultivating, harvesting, transporting and storing. The scope for good manufacturing practices are divided into two categories, *i.e.* milling and refining. The processes involved for milling are sterilisation and oil extraction while for refining are degumming, neutralisation, bleaching and deodorisation.

Even though Codex has not implemented any permissible levels of 3-MCPDE and GE in oils and fats, our industry should be proactive by taking the necessary procedures to bring down the level of these contaminants in refined palm oil. Once the maximum level is implemented, it will be globally accepted as Codex is internationally recognised. The CoP developed by Codex is a guideline for the industry players to address these issues. This article discusses only those practices that are relevant to oil palm and palm oil industries.

MPOB had launched a voluntary certification scheme known as code of good practice for the whole supply chain of palm oil industry namely nursery, estate, palm oil mill, kernel crusher, refinery and bulking facilities. Participants were audited based on the requirements of the scheme and awarded with relevant certificates if all the requirements were complied. The information in this article is based on general observation during the audit exercises of estates, palm oil mills and refineries.

GOOD AGRICULTURAL PRACTICES

Table 1 provides a guideline for the agriculture sector in addressing the formation of the two contaminants. The recommended mitigation measures began with practices for agriculture sector because this is the starting point for oil palm industry. As the first step, planting oil palm with low lipase activity if it is available was suggested. Unfortunately, such oil palm planting material is not yet available because this issue is relatively new to the industry. It might take several years to produce such seedling. All this while, breeders have been concentrating on producing planting materials that could give high yield, dwarf trees and resistant to *ganoderma* attack, namely GenomeSelect (Sime Darby, 2020), PS 1 (Kushairi *et al*., 1999) and YangambiGT1 (FGV, 2020) respectively. Therefore, this option is not possible in the near future.

TABLE 1. POTENTIAL MITIGATION MEASURES FOR REDUCING 3-MCPDE AND GES FOR AGRICULTURE

Sector	Mitigation measures
Agriculture	• Select oil palm plant varieties with low lipase activity, if available. • Minimise use of substances such as fertilisers, pesticides and irrigation water that contain excessive amount of chlorine-containing compounds during oil plant/tree cultivation. • Harvest oil palm fruits when they are at optimal ripeness. Minimise handling of the fruits. Avoid using damaged or overripe fruits. • Transport oil palm fruits to oil mills as soon as possible.

Source: CODEX Alimentarius, CXC 79-2019.

The rest of recommendations for good agriculture practices are being implemented by planters. All plantations have adopted integrated pest management technique by planting beneficial plants such as *Cassia cobanensis* and *Turnera subulata (Figure 1)*. Predators are attracted to the flowers of the plants for the nectar and become a biological agent in controlling bagworm population (Norman *et al*., 1996). Some plantations use barn owl (*Tyto alba*) (*Figure 2*) to control rats' population instead of chemical-based pesticide and combining the application of chemical fertilisers with compost, which would reduce the use of pesticides and chemical fertilisers respectively. These practices would minimise the application of chlorine-containing substances during cultivation.

Harvesters are trained and constantly reminded to harvest only fresh fruit bunch (FFB) of optimal ripeness to avoid being penalised by palm oil mills for delivery of unripe or under-ripe bunches. All FFB should be delivered to palm oil mills within 24 hr and will be graded according to *MPOB Grading Manual* (MPOB, 2015) by qualified grader to ensure that the mill processes only good quality fruits. The delivery of FFB should not be delayed so as to minimise the formation of free fatty acid (FFA). The liberation of FFA by hydrolysis from glycerol led to an increase in diacylglycerol (DAG), a precursor for GE formation. Therefore, suppressing the formation of FFA would inadvertently minimise the level of DAG.

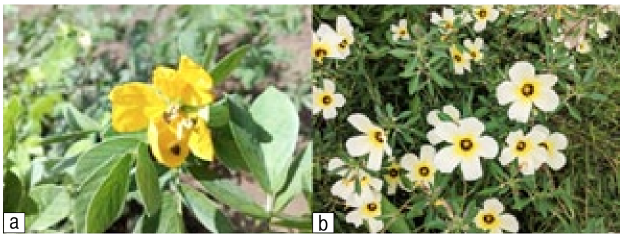

Figure 1. Beneficial plants, (a) Cassia cobanensis *and (b)* Turnera subulata.

Figure 2. Barn owl (Tyto alba).

Many plantations have stopped using intermediate ramp for FFB collection to minimise fruits handling. As an alternative, harvested FFB are loaded onto large steel bins and transported to palm oil mills. Elimination of intermediate ramps at plantations cause less FFB handling, thus minimise bruising of the fruits and consequently reduce the formation of FFA which inadvertently suppresses the formation of DAG. Lipase would speed up hydrolysis, especially on bruised fruit (Swoboda, 1980). Prompt delivery of undamaged FFB to mills would control the formation of FFA and consequently keep DAG at the lowest possible level.

GOOD MANUFACTURING PRACTICE

i. Milling

FFB are delivered to palm oil mills for mechanical process oil extraction. The processes involved are sterilisation, stripping, digesting, oil extraction, screening, clarifying, purifying and vacuum drying. During sterilisation, steam is supplied at temperature around 130°C to inactivate lipase and loosen the fruits from the spikelets. This process generates steriliser condensate which contains small quantity of oil which are usually recovered and put back into production line together with empty fruit bunch liquor as diluent. This practice would negatively affect the quality of crude palm oil (CPO) since the condensate contains high amount of chloride (Rahmat *et al*., 2019). In order to comply with Codex's guideline as mentioned in *Table 2*, the recovered and other residual oils should be sold separately as industrial grade oil. FFA, DOBI, moisture and impurities are regularly monitored as these are part of sales contract. With the emerging 3-MCPDE and GE issues, chloride and DAG contents most likely would be included as part of quality parameter in the future.

Several CPO washing trials using municipal water conducted at MPOB managed to bring down the level of total chloride in the washed oil. This has prompted industrial scale washing trials where the total chloride was successfully reduced from 10 to less than 1 mg kg^{-1}. It is not necessary to use chlorine-free water as recommended by Codex since washing with chlorinated water has been proven to be an effective control measure to reduce the total chloride content, which is a precursor for formation of 3-MCPDE. *Figure 3* illustrates a typical CPO washing process flow.

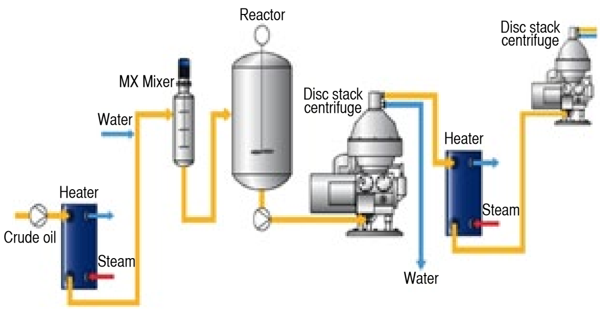

Figure 3. Typical crude palm oil (CPO) washing process flow.

ii. Refining

CPO delivered to refineries will be analysed for FFA and DOBI upon receipt to ensure conformity to the contract and also for setting the refining condition. The amount of phosphoric acid for degumming ranged from 0.05% to 0.2% while bleaching earth ranged from 0.8% to 2.0% of the CPO feed (Basiron, 2005). The quality of CPO would determine the applied dosage; good quality oil requires lower amount of acid and bleaching earth. The feed oil could also be firstly degummed with water, followed by acid to remove hydratable and non-hydratable phosphatides respectively. This degumming technique would require lower acid dosage and make the process less acidic as recommended in *Table 2*.

The second stage of refining is bleaching where impurities and acid are removed from the feed oil by bleaching earth. Acid activated clay is commonly used for bleaching because it has better absorption efficiency as compared to natural clay. It was recommended to use greater amount of bleaching earth with neutral pH. However, this will lead to higher oil loss which refiners have to bear in order to produce refined, bleached and deodorised palm oil (RBD PO) containing low 3-MCPDE and GE. Neutral clay can only be used on exceptionally good quality CPO, *i.e.* with very low FFA and high DOBI.

Extreme temperatures have been reported to influence the formation of 3-MCPDE and GE. Deodorisation temperature for physical refining is within the range of 260°C to 270°C. Therefore, temperature has to be lowered to bring down the level of the contaminants provided that the deodoriser has very strong vacuum and most likely, the residence time has to be prolonged. Refiners can also use dual deodorisation (two-stage deodorisation), *i.e.* a combination of shorter (*e.g.* 5 min at 250°C) and longer (*e.g.* 120 min at 200°C) deodorisation period. The purpose is to reduce thermal load in the oil as a control measure for the formation of contaminants.

Even though physical refining is most common practice in Malaysia, some companies have built small scale chemical refineries to cater for European customer's requirements for low 3-MCPDE content in refined palm oil. The latter has extra neutralisation process where alkali is added to the feed oil to neutralise the FFA followed by addition of hot water to remove soap from the oil phase as shown in *Figure 4*. This provides a kind of washing effect to the oil where inorganic chloride and other water soluble impurities are removed together with the soap.

TABLE 2. POTENTIAL MITIGATION MEASURES FOR REDUCING 3-MCPDE AND GES FOR MILLING AND REFINING

Production stage	Mitigation measures
Milling	• Sterilise oil palm fruits at temperature at or below 140°C. Clean, dry and heat oilseeds to inactivate lipases. • Wash crude vegetable oil with chlorine-free water. • Avoid using residual vegetable oil recovered from solvents or extractions. • Assess precursors (*e.g.* DAG, FFA and chlorine compounds) in crude vegetable oil batches to adjust refining parameters. • Preferentially refine crude vegetable oil with low concentrations of precursors.
Refining	**Degumming** • Use milder and less acidic conditions (*e.g.* either degumming with low concentration of acid or water degumming). • Lower the degumming temperature. **Neutralisation** • Use chemical refining (*i.e.* neutralisation) as alternative to physical refining. **Bleaching** • Use greater amount of bleaching clay. • Use more pH-neutral clays to reduce acidity. **Deodorisation** • Conduct deodorisation at reduced temperature. The temperatures will vary depending on oil's residence time. • Conduct dual deodorisation (two-stage deodorisation) as alternative to traditional deodorisation. • Use stronger vacuum to facilitate evaporation of volatile compounds and to lower deodorisation temperatures.

Source: CODEX Alimentarius, CXC 79-2019.

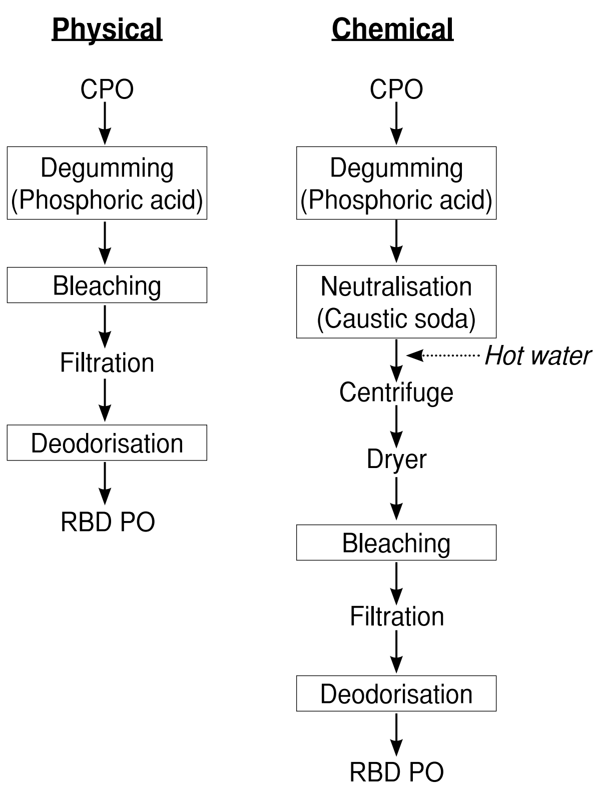

Figure 4. Flowchart of physical and chemical refining.

CONCLUSIONS

Some of the recommendations by Codex have been implemented by our industry players while others are possible to be adopted with some adjustments and modifications especially for manufacturing sectors. CPO washing, use of high dosage of bleaching earth and dual deodorisation are the new norm for palm oil processing sector to bring down the level of 3-MCPDE and GE in refined palm oil. This is to ensure the safety of palm oil by complying with the maximum limit set by the European Union (EU), enhance its image and sustain its position in the highly competitive global market as the way forward. A general observation was that local planters, millers and refiners are ready to adopt most of the Codex guideline.

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