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Review

Toxicology, occurrence and risk characterisation of the chloropropanols in food: 2-Monochloro-1,3-propanediol, 1,3-dichloro-2-propanol and 2,3-dichloro-1-propanol

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ABSTRACT

Great attention has been paid to chloropropanols like 3-monochloro-1,2-propanediol and the related substance glycidol due to their presence in food and concerns about their toxic potential as carcinogens. The other chloropropanols 2-monochloro-1,3-propanediol, 1,3-dichloro-2-propanol and 2,3-dichloro-1-propanol have been found in certain foods, but occurrence data are generally limited for these compounds. 1,3-dichloro-2-propanol has the most toxicological relevance showing clear carcinogenic effects in rats possibly via a genotoxic mechanism. The dietary exposure to 1,3-dichloro-2-propanol is quite low. Calculated "Margins of Exposure" values are above 10,000. It is concluded that the 1,3-dichloro-2-propanol exposure is of low concern for human health. The toxicology of 2,3-dichloro-1-propanol has not been adequately investigated. Its toxicological potential regarding hepatotoxic effects seems to be lower than that of 1,3-dichloro-2-propanol. Limited data show that 2,3-dichloro-1-propanol occurs only in trace amounts in food, indicating that exposure to 2,3-dichloro-1-propanol seems to be also of low concern for human health. The dietary 2-monochloro-1,3-propanediol burden appears to be lower than that of 3-monochloro-1,2-propanediol. An adequate risk assessment for 2-monochloro-1,3-propanediol cannot be performed due to limited data on the toxicology and occurrence in food. This article reviews the relevant information about the toxicology, occurrence and dietary exposure to the chloropropanols 2-monochloro-1,3-propanediol, 1,3-dichloro-2-propanol and 2,3-dichloro-1-propanol.

Contents

Abbreviations: ADH, aldehyde dehydrogenase; BMD, benchmark dose; BMDL10, benchmark dose lower bound 10%; bw, body weight; CYP, cytochrome P450; DCA, 1,3-dichloroacetone; 1,3-DCP, 1,3-dichloro-2-propanol; 2,3-DCP, 2,3-dichloro-1-propanol; EC, the European Commission; EFSA, European Food Safety Authority; IARC, International Agency for Research on Cancer; GSH, glutathione; JECFA, Joint FAO/WHO Expert Committee on Food Additives; HVP, hydrolysed vegetable protein; LD_{50}, lethal dose 50%; 2-MCPD, 2-monochloro-1,3-propanediol; 3-MCPD, 3-monochloro-1,2-propanediol; MOE, margin of exposure; NOAEL, No Observed Adverse Effect Level; PPD, propanediol; ppm, parts per million; SCE, sister chromatid exchange; TC_{50}, toxic concentration 50%.

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1. Introduction

Recently, great attention has been paid to chloropropanols due to the finding that certain fatty acid esters of 3-monochloro-1,2-propanediol (3-MCPD) and the related substance glycidol are present in food. Glycidol (2,3-epoxy-1-propanol) can be formed via dehalogenation from 3-MCPD. Both substances as fatty acid esters can be found at relatively high concentrations in refined vegetable oils and fats (e.g. palm oil) and, therefore, also in vegetable fat-containing products, including infant formula where they are formed as contaminants during processing. Concerns have arisen due to their toxic potential. 3-MCPD is considered a non-genotoxic carcinogen causing kidney tumours, whereas glycidol induces tumours in numerous organs of rodents via genotoxic mechanisms. The toxicological assessment of 3-MCPD and glycidol fatty acid esters in food has been described elsewhere (Bakhiya et al., 2011). There, we concluded that the exposure to 3-MCPD and glycidol esters may pose a safety concern particularly for infants which are fed with commercial infant formulas. However, given the fact that there is no alternative to infant formulas and follow-on formulas for non-breastfeeding infants, we concluded that there is a need to reduce the levels of 3-MCPD and glycidyl fatty acid esters in vegetable fats and in the corresponding fat-containing products (BfR, 2012, 2009, 2007).

Alongside 3-MCPD and glycidol, the chloropropanols 2-monochloro-1,3-propanediol (2-MCPD), 1,3-dichloro-2-propanol (1,3-DCP) and 2,3-dichloro-1-propanol (2,3-DCP) have been found in certain food products (Crews et al., 2003; EC, 2004; Fu et al., 2007). Like 3-MCPD and glycidol, the other chloropropanols may be also present as fatty acid esters in oils and fats (Kuhlmann, 2011; Seefelder et al., 2011). While dichloropropanols could only occur as monoesters, monochloropropanediols can form monoesters and diesters (Seefelder et al., 2011). The molecular structures of unbound and esterified MCPD and DCP molecules are depicted in Fig. 1.

The aim of this article is to review the relevant information about the toxicology, occurrence in food and dietary exposure to the three chloropropanols 2-MCPD, 1,3-DCP and 2,3-DCP. Due to the focus on the risk evaluation of these compounds in food, the main emphasis regarding the toxicological aspects is on oral administration, but other routes of administration are also covered for relevant toxicological issues.

2. Formation and occurrence

1,3-DCP is used as an intermediate in the production of epichlorohydrin which is applied as raw material in the chemical and paper industry. Epichlorohydrin polyamine polyelectrolytes are used as flocculants and coagulants for water purification in drinking water and, therefore, 1,3-DCP is also present as a contaminant in water (Cal/EPA, 2010; IARC, 2012; Kim et al., 2007).

The formation of chloropropanols in food is not fully elucidated but it is suggested that hydrochloric acid and residual lipids from the applied material are the precursors for these substances (Fu et al., 2007; Hamlet et al., 2011, 2002). 3-MCPD and 1,3-DCP are formed during the manufacture of hydrolysed vegetable proteins

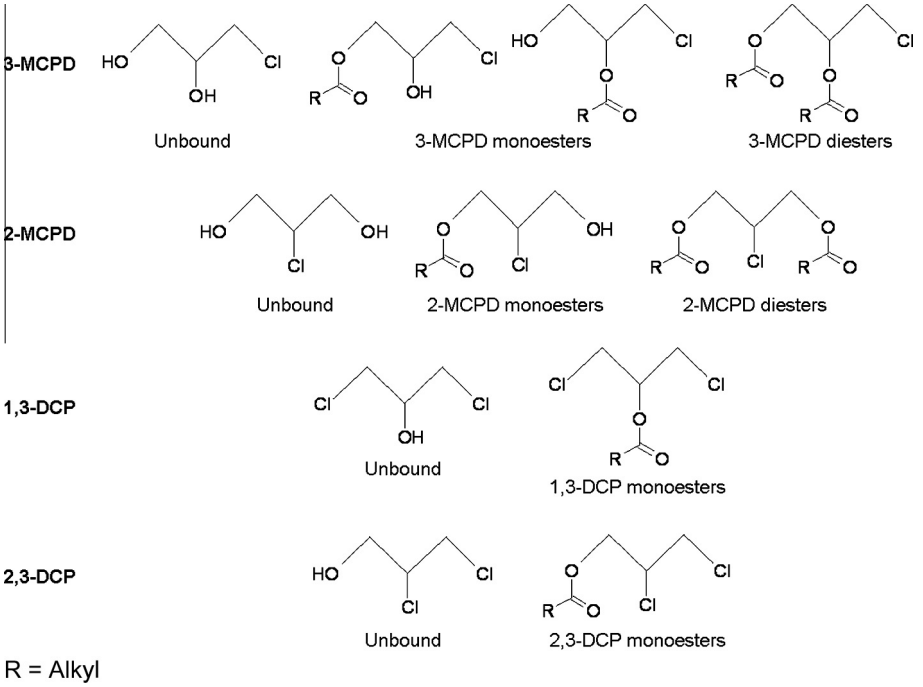

Fig. 1. Chemical structures of the chloropropanols, MCPDs and DCPs and their esters.