Estimation of the dietary intake and risk assessment of food carcinogens (3-MCPD and 1,3-DCP) in soy sauces by Monte Carlo simulation

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Abstract

Quantifiable levels of 3-chloropropane-1,2-diol (3-MCPD) and 1,3-dichloro-2-propanol (1,3-DCP) were found in domestically manufactured soy-based sauces. Selected commercial foods in the Malaysian market (n = 43) were analyzed for their 3-MCPD and 1,3-DCP contents using a validated gas chromatography–mass spectrometry technique. The 3-MCPD and 1,3-DCP contents of the analyzed food samples varied from not detectable levels to 0.1223 ± 0.0419 mg kg⁻¹ and not detectable levels to 0.025 ± 0.0041 mg kg⁻¹, respectively. High concentrations of 3-MCPD, exceeding Malaysia’s maximum tolerable limit of 0.02 mg kg⁻¹, were found in chicken seasoning cubes (mean = 0.0898 ± 0.0378 mg kg⁻¹). Monte Carlo simulation-based health risk assessment revealed that 3-MCPD and 1,3-DCP intakes in the 50th, 95th, and 99th percentiles were lower than 4 µg kg⁻¹ day⁻¹, the limit recommended by JECFA in 2016. Hence, it was concluded that the exposure of Malaysian citizens to chloropropanols through soy sauce consumption does not present a health risk.

1. Introduction

Soy sauces are dark-colored food seasonings used to improve the sensory characteristics of foods. Classically, they are produced by the microbial fermentation of defatted soybeans, wheat gluten, corn meal, and other raw ingredients under suitable conditions. In this process, soy proteins are decomposed to flavor components (FAO, 2012). The fermentation of soy sauces takes approximately four months, depending on the type of bacteria/microbial enzymes used for the fermentation (FAO, 2012). Although the market demand for soy sauces is high, their production is slow and costly. To overcome this limitation, artificial soy sauces are produced by the acid hydrolysis of vegetable proteins without fermentation, allowing the market demand to be met (Christova-Bagdassarian, Tishkova, & Vrabccheva, 2013). Using acid hydrolysis, the time required for the production of soy sauces can be dramatically reduced (from four months to three days on average).

Unfortunately, this accelerated process is known to produce 3-chloropropane-1,2-diol (3-MCPD) and 1,3-dichloro-2-propanol (1,3-DCP) as byproducts of the thermal treatment (Arisseto, Vicente, Furlani, & Toledo, 2013). 3-MCPD and 1,3-DCP are food processing contaminants with potential genotoxic and carcinogenic characteristics (Lee & Khor, 2015; Onami et al., 2014). Of the chloropropanols found in foods, 3-MCPD is the most significant because of its abundance and toxicity. In addition, 3-MCPD has been found to result in kidney and reproductive organ failure based on toxicological animal studies (Arisseto, Silva, Scaranelo, & Vicente, 2017). Moreover, genotoxicity of 3-MCPD has been extensively reported in the last two years (Aasa, Törnqvist, & Abramsson-Zetterberg, 2017; Nohmi, Masumura, & Toyoda-Hokaiwado, 2017). Although the genotoxicity of 3-MCPD is species-specific (toxicity proven for rats but inconclusive for mice), the risks to human health posed by 3-MCPD cannot be completely ignored (Onami et al., 2014). The available toxicity data from in vivo studies indicate that 3-MCPD and 1,3-DCP are cancer-inducing agents; thus, they have been categorized as the possible human carcinogens (Group 2B) and listed under California Proposition 65 (Prop. 65) ([IARC, 2014; OEHHA, 2018]). In other words, these food processing contaminants are considered possibly carcinogenic, but with some uncertainty. In fact, every country has its own maximum tolerable level for 3-MCPD in foods. For instance, the European Union and Malaysia have set maximum limits of 0.02 mg kg⁻¹ for 3-MCPD in soy sauce.