Philippine Journal of Science
150 (6B): 1789-1801, December 2021
ISSN 0031 - 7683
Date Received: 27 Jul 2021

Risk Profiling of 3-MCPD (3-monochloropropane-1,2-diol) in Soy Sauce to the Adult Filipino Consuming Population

Abigail S. Rustia[1]*, **Bebviet Franz R. Bulagao**[1], **Karina Angela D. Bautista**[1], **Deon Mahoney**[2], **Casiana Blanca J. Villarino**[1], **Erniel B. Barrios**[3], and **Mario V. Capanzana**[4]

[1]Department of Food Science and Nutrition, College of Home Economics
University of the Philippines Diliman, Quezon City
National Capital Region 1101 Philippines
[2]Produce Marketing Association Australia–New Zealand Limited
(PMA A-NZ) Ltd. Docklands, Victoria 3008 Australia
[3]School of Statistics, University of the Philippines Diliman, Quezon City
National Capital Region 1101 Philippines
[4]Food and Nutrition Research Institute, Department of Science and Technology
Taguig, National Capital Region 1630 Philippines

Soy sauce is one of the commonly consumed food items in the Philippines because of its vast applications as a regular sauce and a condiment in various food dishes. One method used to produce soy sauce is chemical hydrolysis that involves acid hydrolysis of vegetable protein under high temperatures, which may generate a chemical by-product called 3-monochloropropane-1,2-diol (3-MCPD). Exposure to 3-MCPD may potentially cause adverse health effects to humans such as kidney, liver, and reproductive organ failure, as well as infertility and carcinogenicity. Thus, this study aimed to establish a profile on the potential risk associated with the consumption of soy sauce with 3-MCPD in the Philippines. This study included risk profile conceptualization, literature review, and identification of uncertainties and variabilities to formulate assumptions, which were then used in the dietary exposure (DE) assessment and estimation of risk of the adult Filipino consuming population to 3-MCPD in soy sauce. Analysis showed that the soy sauce samples (n = 19) collected from identified supermarkets and wet markets in the Philippines contained 3-MCPD levels below the maximum level (ML) of 0.4 mg/kg set by the 2019 edition of the Codex General Standards for Contaminants and Toxins in Food and Feed. With these generated data on the hazard levels, the high consumer (97.5th) percentile soy sauce consumption data from the Philippine Department of Science and Technology–Food and Nutrition Research Institute (DOST-FNRI), and the assumed body weight of an adult Asian, the DE of the adult Filipino consuming population to 3-MCPD in soy sauce was estimated to be 0.0327–0.1636 µg/kg body weight (bw)/d, which was lower than 4 µg/kg bw – the latest provisional maximum tolerable daily intake (PMTDI) set by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) in 2016. Based on these findings, the consumption of soy sauce showed no appreciable risk to the health of the Filipino consuming population.

Keywords: 3-MCPD, Philippines, risk profile, soy sauce

*Corresponding Author: asrustia@up.edu.ph

INTRODUCTION

Soy sauce, commonly known as *toyo* in the Philippines, is a brown and salty liquid made from fermented soybeans and wheat or other cereals, hydrolyzed soybean protein, or a combination of both (Luh 1995; Chinte-Sanchez 2008). It is used as a condiment in many Filipino dishes such as *adobo*, *patatim*, and *tapa*, and sometimes consumed as part of a dipping sauce or *sawsawan*, which is common in Filipino food culture (Chinte-Sanchez 2008; Fukutome n/d). In the dietary survey conducted by the DOST-FNRI in 2015, soy sauce is one of the commonly consumed food items in the Philippines regardless of the place of residence (rural or urban) and wealth quintile (poorest, poor, middle, rich, or richest) (DOST-FNRI 2016). Moreover, dried beans, nuts, and seeds where soy sauce is categorized as having a mean one-day household consumption of 34g/d, which is 1.0% of the total intake (DOST-FNRI 2016). Moreover, soy sauce comprised the greatest proportion of consumption among all the components under this category (soy sauce: 35.3%, *munggo*: 7.3%, soybean curd: 0.7%, green pea: 0.7%, and *abitsuwelas*: 0.3%) (DOST-FNRI 2016).

Soy sauce may be produced through various processes such as traditional fermentation, chemical hydrolysis, or a combination of both (Luh 1995; FAO/WHO 2012). The process of soy sauce production, however, may introduce the formation of a chemical hazard called 3-MCPD, which is a chemical by-product of the chemical hydrolysis method during the step of acid hydrolysis of vegetable protein under high temperatures (70–135 °C) (Chinte-Sanchez 2008; FAO/WHO 2012; Lee and Khor 2015). The formation of 3-MCPD is due to the reaction between lipids – particularly triacylglycerols, phospholipids, or glycerol, and chloride ions from the added hydrochloric acid (EFSA 2013; Collier *et al*. 1991; IFST 2018). Moreover, 3-MCPD may also form in soy sauce when acid-hydrolyzed vegetable protein (acid-HVP) is used as one of the ingredients (FAO/WHO 2012; Lee and Khor 2015). Based on animal studies, exposure to 3-MCPD may potentially cause kidney, liver, and reproductive organ failure, as well as infertility and carcinogenicity (Cho *et al*. 2008a, b; Bakhiya *et al*. 2011; IARC 2012; Arisseto *et al*. 2013).

To prevent and minimize the presence of 3-MCPD in soy sauce, the Code of Practice for the Reduction of 3-MCPD during the Production of Acid-HVPs and Products that Contain Acid-HVPs (CAC/RCP 64-2008) was developed by the Codex Alimentarius Commission (CAC) (FAO/WHO 2012). This document (CAC/RCP 64-2008) describes ways to reduce 3-MCPD in acid-HVPs like soy sauce through 1) controlling the parameters (*i.e.* heating time and temperatures) during the acid hydrolysis and neutralization steps; 2) conducting alkaline hydrolysis after the acid hydrolysis step using a food-acceptable alkali such as potassium hydroxide, sodium hydroxide, ammonium hydroxide, or sodium carbonate; and 3) using sulfuric acid instead of hydrochloric acid during the hydrolysis step. Meanwhile, in the Philippine setting, standards or regulations are currently being imposed for the manufacturers to follow to ensure that 3-MCPD levels in soy sauce do not exceed the ML of 0.4 ppm that is advised by the Philippine Food and Drug Administration of the Department of Health (DOH-FDA 2011). The Philippine FDA has adopted this standard from the standard ML of 3-MCPD in liquid condiments containing acid hydrolyzed vegetable proteins by General Standard for Contaminants and Toxins in Food and Feed (CXS 193-1995 e. 2019) (DOH-FDA 2011; CAC 2019).

With soy sauce being part of the top consumed items by the Filipino consuming population, it is important to gather data and up-to-date information to determine the health risks that may be caused by the consumption of soy sauce with 3-MCPD. As of the current study, there are limited local studies on 3-MCPD in soy sauce as compared to international studies – which included the determination of 3-MCPD levels in soy sauce, DE assessment, and potential risks associated with the consumption of food containing 3-MCPD (Crews *et al.* 2003; Nyman *et al.* 2003; Arisseto *et al.* 2013; Christova-Bagdassarian *et al.* 2013). Furthermore, the Philippines has yet to develop a code of practice that is particular to the prevention of 3-MCPD in soy sauce. Only the Code of Practice for the Reduction of 3-MCPD during the Production of Acid-HVPs and Products that Contain Acid-HVPs (CAC/RCP 64-2008) that was established by the CAC is available. These, thus, strengthen the need to develop a risk profile that is specific for 3-MCPD in soy sauce.

Considering these, the Philippine DOST-funded project entitled "Risk Profiling of Hazards in Philippine Foods to Support National Risk Management," also known as the "Philippine Food Safety Risk Profiling Project" (PRPP), recognized the need for and initiated this study to establish a risk profile on the potential risk associated with the consumption of soy sauce contaminated with 3-MCPD to the Filipino consuming population. Specifically, this study sought to conceptualize the risk profile, review related literature, identify uncertainties and variabilities for the formulation of assumptions, assess the exposure pathway of 3-MCPD in the food value chain of soy sauce through sampling and analysis, and characterize the risk in the consumption of soy sauce contaminated with 3-MCPD.

Risk profiling gives preliminary information on the risk of identified food safety issues to the Filipino consuming population, thus allowing the food safety risk managers to explore control options and mitigate the risks even before the food safety issue arises (WHO 2021). The risk

profiling of 3-MCPD in the consumption of soy sauce by the adult Filipino consuming population is of relevance to serve as reference material for the national risk managers to aid in the decision making and proposing possible mitigation measures.

In preparing this risk profile, the following risk management questions were asked:

1. What is 3-MCPD and why is it a concern when it comes to our food?
2. How is 3-MCPD formed in soy sauce?
3. What factors affect the level of 3-MCPD in soy sauce?
4. How are we exposed to this hazard?
5. What is the level of the hazard that will cause illness and/or, death?
6. Are there any available standards/maximum allowable limit for the hazard?
7. What measures are available to control 3-MCPD in soy sauce?

MATERIALS AND METHODS

Conceptualization of a Food Safety Risk Profile

The food hazard:commodity combination was identified and decided upon after consultations with the risk analysis expert of PRPP – as well as through forum and discussion meetings with the DOH-FDA, the agency mandated to set food safety standards for processed and pre-packaged foods such as soy sauce (Official Gazette 2015). This risk profile focuses on 3-MCPD as the hazard and soy sauce in the Philippines as the food commodity.

The outline of this risk profile was conceptualized with reference to existing risk profiles from international organizations with numerous works on food safety risk assessment such as the FSANZ (Food Standards Australia New Zealand), CAC, and FAO/WHO and based on consultations with the PRPP risk analysis expert.

Review of Related Literature

The review of related literature in this study was conducted to gather and establish available information for each of the conceptualized elements of this risk profile. The literature review of the study covered the scientific studies, standards, monitoring, evaluation, health risk assessment, reports of illnesses, and statistics regarding 3-MCPD. The terms "3-MCPD," "3-monochloropropane-1,2-diol," "soy sauce," "risk profile," "risk assessment," "risk profiling," "food safety," "distribution," "pharmacokinetics," and "health effects" were used either individually or in combinations with each other to search online databases such as Google, Google Scholar, ScienceDirect, Wiley Online Library, ResearchGate, Taylor & Francis Online, Elsevier, the FAO/WHO Joint Expert Committee on Food Additives (JECFA), CAC, among others, for literature dated from the year 2000 up to present. However, some literature from the 1980s and 1990s were also included due to the limited number of recent publications on the topic. Collected literature was then organized and summarized into the following classifications: 3-MCPD (hazard), soy sauce (commodity), and 3-MCPD in soy sauce (hazard-commodity combination).

Access to pertinent documents relevant to the study of 3-MCPD in soy sauce was requested from collaborating agencies and offices such as the DOH-FDA and the DOST-FNRI and was used in the exposure pathway assessment part of this study.

Identification of Uncertainties and Variabilities to Formulate Assumptions

Prior to the conduct of risk profiling, limitations of the study were identified to determine the range of information needed to adequately reflect the Philippine scenario. The study is primarily limited to soy sauce available in the Philippines, regardless of its origin of production (*i.e.* locally produced or imported), and 3-MCPD as the specific hazard in the commodity. In addition, this study is also limited to 3-MCPD in soy sauce only. Other sources of 3-MCPD in the diet are not accounted for in the calculation of DE.

However, uncertainties and variabilities were identified along the process of risk profiling. These uncertainties are the data gaps needed to be addressed or minimized to further the risk assessment and to come up with a more comprehensive risk estimate for the Filipino consuming population. Meanwhile, the variabilities in a risk assessment process are the measurements within a defined population such as food consumption rates and expected lifetime, which cannot be controlled and may only be represented by their moments (*e.g.* mean, variance, *etc.*) with precision (FAO 1995).

Exposure Pathway Assessment

Survey and sampling. A survey and sampling were conducted to generate data on the 3-MCPD levels in soy sauce in the Philippines. The sampling design followed was based on directed or targeted sampling (CXG 71-2009) (CAC 2014b), particularly purposive sampling, and complete enumeration as consulted with the statistical

science expert. The sampling plan particularly targeted areas 1) where most manufacturing plants based on the list from the DOH-FDA were located; 2) with the highest mean one-day *per capita* soy sauce consumption based on the disaggregated 2015 National Nutrition Survey consumption data acquired through a memorandum of understanding with the DOST-FNRI (notarized 2020, pers. comm.); and 3) with high population based on the Philippine Statistics Authority (PSA 2017). From this, the sampling locations identified were supermarkets in the National Capital Region (NCR) and wet markets in NCR and Region 2 (Isabela). The sampling was conducted from November 2019–December 2019.

Sample analysis. Soy sauce samples (n = 20) were submitted to the Philippine Institute of Pure and Applied Chemistry (PIPAC) for 3-MCPD analysis using the gas chromatography–mass spectrometric detection (GC-MS) method (AOAC 2000.01) (AOAC 2002).

Analysis of data. Results from the analysis were tabulated and summarized using Microsoft Excel (2016). Values below the limit of detection (LOD) were reported as equal to the LOD value of the method used, which is 0.1 ppm. Minimum, maximum, and mean ± standard deviation values were calculated.

Calculation of DE assessment. Local food consumption data of soy sauce was acquired from the DOST-FNRI (2020) to establish the baseline DE estimate of Filipinos. The DE was estimated and calculated using the equation provided by the WHO (2020):

$$DE = \frac{\sum(\textit{Food consumption x Chemical concentration in the food})}{\textit{Mean body weight (kg)}} \quad (1)$$

The estimated DE of the Filipino adult consuming population was calculated using the following information: 1) generated data on 3-MCPD levels in soy sauce, 2) the high consumer (97.5th) percentile consumption data (18 g/d) and average (mean) consumption data (6.5 g/d) of soy sauce by the adult (20–59 yr old) Filipino consuming population (n = 3543) from the DOST-FNRI (pers. comm. 2020), and 3) an assumed average weight of 55.0 kg for Asian adults from the WHO (2020). The DE estimates were then compared with the PMTDI of 4 µg/kg bw set during the 83rd meeting of JECFA in 2016 (TRS 1002-JECFA 83/104) by calculating the % PMTDI. The 97.5th percentile consumption of the consuming population was considered in this study to avoid underestimation of high exposure levels, because underestimation may occur when consumption of the whole population which includes non-consumers is used (WHO 2020).

Calculation of Risk Estimate for Risk Characterization

A risk estimate was generated using an integration of the adverse health effects of the exposure to 3-MCPD in the hazard characterization step, the exposure of the Filipino population to 3-MCPD in soy sauce in the exposure assessment step, and the generated data on 3-MCPD levels in soy sauce. Moreover, established assumptions, uncertainties, and variabilities from this study were also considered.

RESULTS AND DISCUSSION

Conceptualization of the Risk Profile

The FAO/WHO (2009) describes a risk profile as a "qualitative risk assessment." Most food safety risk profiles developed by European Commission and New Zealand Food Safety were observed, similar to risk assessment reports developed by FAO and WHO consisting of the following steps: hazard identification, hazard characterization, exposure assessment, and risk characterization.

The outline of the risk profile of 3-MCPD in soy sauce in the Philippines was conceptualized with reference to FSANZ (2003), CAC (CXG 63-2007 and CXG 30-1999) (CAC 2008, 2014a), and FAO/WHO (2003), and in consultation with an international food safety expert. The risk profile outline includes 1) the statement of the purpose with the risk management questions; 2) information about the hazard and the food, which involves the four aspects of risk assessment; and 3) the availability of hazard control measures, both in the local and in the international scene. This risk profile was outlined in such a way that will serve as a baseline template for other stakeholders who will also conduct risk profiling activities for other food hazard: commodity combinations.

The results of the 1) consultation with the agencies and experts, 2) review of literature, and 3) exposure pathway assessment were segregated according to the outline of the food safety risk profile conceptualized for the project, under which this study was conducted.

Review of Related Literature

Risk profiling utilizes a review of related literature to give an overview of the available information from various sources regarding the food safety risk profile sections, "2. Hazard and Food" – particularly the subsections "2.1 Hazard Identification" and "2.2 Hazard Characterization" – and "3. Availability of Hazard Control Measures." Key findings during the development of the risk profile are discussed hereafter, addressing the risk management questions identified.

Hazard identification. 3-MCPD is a by-product of the chemical reaction between lipids – specifically, triacylglycerols, phospholipids or glycerol, and chloride ions in either fat-based or fat-containing foods – which undergone high temperature processing such as by roasting, frying, and baking (Collier *et al*. 1991; EFSA 2013; IFST 2018). The formation of 3-MCPD may be affected by the following factors: a) use of 3-MCPD containing raw materials; b) storage of both raw materials and prepared products; c) washing using chlorinated water; d) processing at high temperatures; e) other food processes or preparation such as baking, evaporation, fermentation, malting, pasteurization, roasting, smoking, spray drying, sterilization, and UHT; f) food contact materials migration; and g) diacetyl glycerol and polar compounds levels in fats and oils (Baer *et al*. 2010; IARC 2012; IFST 2018). In soy sauce, 3-MCPD formation happens during its production, which applies various processes such as 1) fermentation of a mixture of soybeans plus other cereal grains such as wheat, water, and salt; 2) acid-mediated hydrolysis of defatted soybeans; and 3) combination of the soy sauce produced using the two processes mentioned (Luh 1995; FAO/WHO 2012).

Hazard characterization. Exposure to 3-MCPD is mainly *via* ingestion, with the compound distributed in body fluids (IARC 2012; León *et al*. 2008). In a study conducted in male rats, after ingestion, 3-MCPD is absorbed rapidly in the gastrointestinal tract, distributed to various tissues, metabolized in the liver, and then flushed out of the body *via* the kidneys (Xiao *et al*. 2003). In a study conducted in rats, 30% of the 3-MCPD dose injected was exhaled as carbon dioxide (CO_2) and 8.5% was excreted as urine within 24 h post-dosing (Bakhiya *et al*. 2011; IARC 2012). Based on animal studies, exposure to 3-MCPD may have toxic health effects such as kidney-related diseases, liver failure, reproductive organ failure, anemia, infertility, genotoxicity, immunotoxicity, and carcinogenicity – especially when exposed repeatedly (Cho *et al*. 2008a, b; Bakhiya *et al*. 2011; IARC 2012; Arisseto *et al*. 2013; FAO/WHO 2018; Xing *et al*. 2019). Thus, JECFA has set a PMTDI of 4 µg/kg bw/d for 3-MCPD and 3-MCPD esters singly or in combination (to be expressed as 3-MCPD equivalents) during their 83rd meeting in 2016 (TRS 1002-JECFA 83/104).

Identification of Uncertainties and Variabilities to Formulate Assumptions

Uncertainties or gaps identified. The uncertainties or gaps identified in the study were the following:

1. limited local and international studies related to 3-MCPD in soy sauce;
2. limited dose-response studies were conducted for 3-MCPD;
3. limited, no recent, or no available reports of poisoning or illnesses directly associated with the consumption of soy sauce or other 3-MCPD-containing food products; and
4. limited local laboratories that test for 3-MCPD in soy sauce.

Variabilities. The variabilities were identified along the process of risk profiling. As defined by the FAO (1995), variabilities in a risk assessment process are the measurements within a defined population such as food consumption rates and expected lifetime, which cannot be controlled and may only be represented by their moments (*e.g.* mean, variance, *etc.*) with precision:

1. the difference in the consumption of soy sauce per region or province, and per age group; and
2. the difference in the ingredients, formulations, and processes used to produce soy sauce.

Assumptions. The limitations, uncertainties, and variabilities identified were considered in the formulation of the following assumptions:

1. the disaggregated consumption data for soy sauce acquired through a memorandum of understanding with the DOST-FNRI (notarized 2020, pers. comm.) represents the consumption of all male and female Filipino adult (20–59 yr old) consuming population in the Philippines;
2. the high consumer percentile value, particularly the 97.5th percentile consumption data, of the Filipino consuming population was used to provide the most conservative estimate in the computation of the DE (WHO 2020);
3. 3-MCPD possibly consumed is mainly from soy sauce only;
4. the bw of the adult Filipino population is equal to the assumed bw for the adult Asian population (55 kg) by the WHO (2020);
5. soy sauce products available in NCR are also the products available in the other regions of the Philippines as most of the manufacturing plants are in NCR;
6. the lowest and the highest 3-MCPD level based on the laboratory results from the analysis are identified to be the minimum and maximum limits, respectively, to which a person may be exposed; and
7. the minimum concentration used is the LOD of 0.1 ppm for soy sauce samples with levels less than the LOD.

Exposure Assessment

3-MCPD levels in soy sauce in the Philippines. As shown in Table 1, results showed that the 3-MCPD levels range from 0.1–0.5 mg/kg with a mean of 0.120 ± 0.09 mg/kg. Out of the 20 samples, 19 were found to have 3-MCPD levels less than the LOD of 0.1 mg/kg and the ML of 0.4 mg/kg 3-MCPD (CXS 193-1995 e. 2019) for liquid condiments containing acid hydrolyzed vegetable protein (CAC 2019). For soy sauce samples with levels below the LOD (0.1 mg/kg), the presence of 3-MCPD in minimal amounts may be attributed to the controlled practices applied during soy sauce production, especially the acid hydrolysis step where 3-MCPD formation usually occurs (FAO/WHO 2012). In addition, the inclusion of hydrolyzed soybean protein as one of the ingredients on some of the soy sauce samples may have also contributed to the amount of 3-MCPD present, as hydrolyzed soybean protein may initially contain 3-MCPD because of the process it had undergone (FAO/WHO 2007; Christova-Bagdassarian *et al.* 2013).

Meanwhile, one soy sauce sample had a 3-MCPD level exceeding the regulatory ML. Based on studies, the 3-MCPD level is affected by the acid treatment done during the hydrolysis step in the production of soy sauce, especially when it is not carefully done (Nyman *et al*. 2003; FAO/WHO 2012). The high level of 3-MCPD obtained in this study should be verified with the manufacturer through the DOH-FDA, the food safety regulatory agency for processed foods. Moreover, unlike traditional fermentation, acid hydrolysis allows the faster breakdown of the compounds necessary for the flavor and aroma (Crews *et al*. 2003; Lee and Khor 2015). In addition, the type of acid used may also affect the 3-MCPD levels (FAO/WHO 2012). For example, the possibility of the 3-MCPD formation increases when hydrochloric acid (HCl) is used unlike sulfuric acid as HCl provides chloride ions, which are important components for the formation of 3-MCPD (Lee and Khor 2015).

Table 1. 3-MCPD levels in soy sauce (n = 20)[a] in the Philippines in 2019.

	3-MCPD levels[b,c] (mg/kg)	ML of 3-MCPD[d] (mg/kg)
Minimum[e]	0.1	
Mean ± SD	0.120 ± 0.09	0.4
Maximum	0.5[f]	

[a]n = number of samples
[b]Data were generated from this study by the Philippine Food Safety Risk Profiling Project in 2019
[c]Method: GC-MS; LOD: 0.1 ppm; LOQ (limit of quantification): 0.4 ppm; ppm = mg/kg
[d]ML set by CAC (CXS 193-1995 e. 2019) and was adopted by the Philippine DOH-FDA
[e]Levels lower than the LOD (0.1 mg/kg) were declared as 0.1 mg/kg
[f]One sample exceeded the ML

DE. The calculated DE for the adult Filipino consuming population (20–59 yr old, 97.5th percentile) ranged from 0.0327–0.1636 µg/kg bw/d with a mean DE of 0.0393 µg/kg bw/d (see Table 2). Meanwhile, the average (mean) adult Filipino consuming population had a calculated DE ranging from 0.0118–0.0591 µg/kg bw/d with a mean of 0.0142 µg/kg bw/d. These results show that soy sauce only contributes to about 0.82–4.09% [for high (97.5th) consumers] and about 0.30–1.48% [for average (mean) consumers] of the PMTDI of 4 µg/kg bw set during the 83rd meeting of JECFA in 2016 (TRS 1002-JECFA 83/104).

Risk Characterization

The calculated DE estimates are below the PMTDI of 4 µg/kg bw (JECFA 2016). Hence, given the available data at the time of evaluation of the DE of the consuming population, the consumption of soy sauce contributes little to 3-MCPD exposure and does not pose an appreciable risk to the health of the adult Filipino consuming population (20–59 yr old) (Chung *et al*. 2013). Note that this estimated DE is based on the established assumptions, uncertainties, variabilities, and the data gathered from this study.

Availability of Hazard Control Measures

Control measures employed. General Standard for Contaminants and Toxins in Food and Feed (CXS 193-1995 e. 2019) has set an ML of 0.4 ppm for 3-MCPD in liquid condiments containing acid hydrolyzed vegetable proteins (CAC 2019). This standard was then adopted by the Philippine DOH-FDA that they announced through an advisory (FDA No. 2010-008, Memorandum on the Adoption of the CODEX Standards on Food Contaminants in Processed Food), which regulated establishments – specifically importers, local manufacturers/processors, distributors, repackers, and retailers – through compliance with the new ML of 3-MCPD in soy sauce (DOH-FDA 2011). In addition, there is the Philippine Standard for Soy Sauce (PNS 274:1993) (as cited by Chinte-Sanchez 2008), which includes the requirements and methods of test for soy sauce (Chinte-Sanchez 2008). In 2008, the CAC developed the Code of Practice for the Reduction of 3-MCPD during the Production of Acid-HVPs and Products that Contain Acid-HVPs (CAC/RCP 64-2008) (FAO/WHO 2012). This Code of Practice includes the good manufacturing practice and the manufacturing process of acid-HVP at a commercial scale.

Analysis of the Developed Food Safety Risk Profile of 3-MCPD in Soy Sauce

A list of information needed to complete a risk profile or make a comprehensive decision based on a risk

Table 2. Estimated DE of adult (20–59 yr old) Filipino consuming population (mean and 97.5th percentile) to 3-MCPD in soy sauce.

Mean bw [a]	**Soy sauce consumption** [b]		**3-MCPD level**		**DE**		**PMTDI**	**% PMTDI**	
kg	g/d		mg/kg		µg/kg bw per day		µg/kg bw		
	High consumer (97.5th percentile)	**Average consumer (mean)**			**High consumer (97.5th percentile)**	**Average consumer (mean)**		**High consumer (97.5th percentile)**	**Average consumer (mean)**
55	18	6.5	Minimum	0.1[c]	0.0327	0.0118	4.00[d]	0.82	0.30
			Maximum	0.5	0.1636	0.0591		4.09	1.48
			Mean	0.120	0.0393	0.0142		0.98	0.35

[a]Mean body weight of the adult Asian population (WHO 2020)
[b]Soy sauce consumption of the consuming population (n = 3543) belonging to age group 20–59 yr old (DOST-FNRI 2020)
[c]Values less than the LOD is reported as 0.1 mg/kg
[d]PMTDI for 3-MCPD from the 83rd meeting of JECFA in 2016 (TRS 1002-JECFA 83/104)

profile was consolidated in Table I (Appendix II). It reiterates the information readily available for each section of the risk profile – namely, hazard identification, hazard characterization, exposure assessment, risk characterization, and availability of hazard control measures. The available information found in this study is mostly from local and international publications, reports, and scientific studies, as well as government agencies (*i.e.* DOH-FDA, DOST-FNRI) and websites. The table also includes the data gaps identified especially in the Philippine context, which may be presented to risk managers for further action.

CONCLUSION

The risk profile developed in this study brings together information on the risks that may be associated with the consumption of soy sauce with 3-MCPD in the Philippines that would help risk managers (*i.e.* DOH-FDA) in making decisions on the consumption of soy sauce contaminated with 3-MCPD and, if necessary, take further action. This risk profile utilizes the risk assessment framework – which includes hazard identification, hazard characterization, exposure assessment, and risk characterization – relevant to the consumption of soy sauce contaminated with 3-MCPD. It identifies the gaps needed to be addressed to be able to conduct a full-blown risk assessment and to come up with a comprehensive risk characterization. Through the risk profiling process, data gaps were identified – including limited local studies related to 3-MCPD in soy sauce in the Philippines, limited dose-response studies for 3-MCPD, limited local laboratories that test for 3-MCPD in soy sauce, and limited to no available reports of poisoning or illnesses directly associated with the consumption of soy sauce or other 3-MCPD-containing food products.

Results from the exposure assessment showed that 3-MCPD levels in soy sauce samples (n = 20) were generally below the ML of 0.4 mg/kg set by CAC for 3-MCPD in liquid condiments containing acid hydrolyzed vegetable protein. Meanwhile, the DE estimates of the adult Filipino consuming population (20–59 yr old, 97.5th percentile) ranged from 0.0327–0.1636 µg/kg bw/d, which are lower than the PMTDI of 4 µg/kg bw/d. This shows that consumption of soy sauce only contributes to about 0.82–4.09% of the PMTDI and does not pose a major health risk to the adult Filipino consuming population. However, it should be noted that the DE estimates are based on the established assumptions, uncertainties, variabilities, and the data gathered in this study. In addition, it is also important to note that there are other potential sources of 3-MCPD such as edible oils and fats, bread crust, toast bread, doughnuts, crisps, roasted coffees, meat and meat products, potato and potato products, bakery products, and smoked products (Baer *et al.* 2010; Jedrkiewicz *et al*. 2016; IFST 2018; Mikulikova *et al*. 2018). It is suggested that a total diet study be conducted to ascertain the actual DE of Filipinos to 3-MCPD.

ACKNOWLEDGMENTS

The project team wishes to acknowledge the following agencies:

- the DOST as the funding agency;

- the University of the Philippines Diliman (UPD) through the Department of Food Science and Nutrition of the College of Home Economics as the implementing agency;
- the DOST through the Philippine Council for Industry, Energy and Emerging Technology Research and Development as the funding monitoring agency; and
- the UPD through the Research Management Office of the Office of the Vice Chancellor for Research and Development as the implementing monitoring agency.
- The project team would also like to thank the following collaborating offices:
- the DOST-FNRI for access to the food consumption data on soy sauce, and
- the DOH-FDA for providing the list of soy sauce manufacturers in the Philippines.

The project team would also like to thank the PIPAC laboratory for the conduct of analytical services relevant to the generation of data on hazard levels.

NOTES ON APPENDICES

The complete appendices section of the study is accessible at https://philjournsci.dost.gov.ph

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APPENDIX I

Ethical Considerations

The exposure pathway assessment conducted for the PRPP, particularly in this study, involved interactions with the stakeholders. As such, the project has applied for ethics clearance through the National Ethics Committee (NEC) of the DOST–Philippine Council for Health Research and Development and the Philippine National Health Research System. The application has been approved with the NEC Code: 2019 014 Rustia Hazards (20190822-115 NEC).

Risk Profile Outline

The risk profile outline includes the following:

1. Statement of purpose
   - 1.1. Risk management questions
2. Hazard and food
   - 2.1. Hazard identification
     - 2.1.1. Sources of the hazard
     - 2.1.2. Hazard in the specific food
   - 2.2. Hazard characterization
     - 2.2.1. Distribution and pharmacokinetics
     - 2.2.2. Adverse effects
     - 2.2.3. Dose response
     - 2.2.4. Establishment of food safety limits (health-based guidance values): general population
     - 2.2.5. Philippine reports of poisoning or illness
   - 2.3. Exposure assessment
     - 2.3.1. 3-MCPD levels in soy sauce in the Philippines compared with overseas data
     - 2.3.2. Consumption information to establish baseline DE estimate
     - 2.3.3. Comparison of Philippine DE estimates with overseas estimates
     - 2.3.4. Other foods contributing to the DE to the hazard
   - 2.4. Risk characterization
     - 2.4.1. Estimate of risk for the general adult Filipino population
     - 2.4.2. Adverse effect levels of 3-MCPD applied to Philippine exposures
     - 2.4.3. Uncertainties and variabilities
3. Availability of hazard control measures
   - 3.1. Existing control measures in the Philippines: regulatory and advisory
   - 3.2. Control measures employed overseas
   - 3.3. Control options

Additional Information

1. Hazard identification is defined by FAO/WHO (2003) as "the identification of biological, chemical, and physical agents capable of causing adverse health effects and which may be present in a particular food or group of foods." Hazard identification includes the following: sources of the hazard and hazard in the specified food.
2. Hazard characterization is defined by FAO/WHO (2003) as "the qualitative and/or quantitative evaluation of the nature of the adverse health effects associated with biological, chemical, and physical agents, which may be present in food."
3. Exposure assessment includes the following: dietary hazard level in soy sauce in the Philippines compared with overseas data, consumption information to establish baseline DE estimate, comparison of Philippine DEs with overseas estimates, and major contributing foods.
4. Risk characterization includes the following: estimate of risk for the Philippines; adverse effects levels applied to Philippine exposures; and uncertainties, variabilities, and assumptions.

APPENDIX II

Analysis of the Developed Food Safety Risk Profile of 3-MCPD in Soy Sauce

Table I. List of needed information, available information, and gaps identified in the study.

Needed information	Available information	Gaps identified
Hazard identification	- Reports on 3-MCPD from FAO/WHO (2012)	- Information gathered regarding 3-MCPD mostly from internationally published papers
a. Definition	- International publications on 3-MCPD	
b. Hazard in the specific food		
c. Sources of 3-MCPD		
Hazard characterization	- Overseas studies on distribution and pharmacokinetics, adverse health effects of 3-MCPD, and dose response	- Limited to no available dose-response studies conducted in the Philippine context relevant to the consumption of 3-MCPD
a. Distribution and pharmacokinetics		
b. Adverse health effects		
c. Dose response	- Reports on 3-MCPD from FAO/WHO (2012, 2018), IARC (2012), and DOH-FDA (2011)	- Limited, no recent, or no available reports of poisoning or illnesses directly associated with the consumption of soy sauce contaminated with 3-MCPD in the Philippines
d. Establishment of safe limits: Filipino adult consuming population		
e. Philippine reports of poisoning or illness	- HBGVs (PMTDI) from JECFA, as set during the 83rd meeting of JECFA in 2016 (FAO/WHO 2018)	
	- ML from Philippine DOH-FDA, as adopted from CAC	
Exposure assessment	- Data generated from this study	- Limited local laboratories capable of testing 3-MCPD in soy sauce
a. Philippine data for dietary hazard concentrations compared with overseas data	- Disaggregated mean and percentile soy sauce consumption of Filipino consumers by age group from DOST-FNRI (2020, pers. comm.)	
b. Consumption information to establish baseline DE estimate		
c. Comparison of Philippine DEs with overseas estimates	- - Average bodyweight of the Asian population from WHO (2020)	
d. Major contributing foods	- Publications on the determination of 3-MCPD levels in soy sauce and related products and DE estimates from different countries (Netherlands, Poland, Brazil, Singapore, and Hong Kong)	
Risk characterization		
a. Estimate of risk for the Philippines	- Calculated estimated DEs of the adult Filipino consuming population to 3-MCPD in soy sauce	- No available clinical studies directly associating 3-MCPD as the cause of the occurrence of adverse health effects in the Philippines
b. Adverse effects level applied to Philippine exposures		
c. Uncertainties, variabilities, and assumptions		

Needed information	Available information	Gaps identified
Availability of hazard control measures		
a. Existing control measures in the Philippines b. Control measures employed overseas c. Control options	- PNS for soy sauce - DOH-FDA memorandum on ML for soy sauce (FDA No. 2010-008) (DOH-FDA 2011) - Code of practice for the reduction of 3-monochloropropane-1,2-diol during the production of acid-HVPs and products that contain acid-HVPs - Reports on 3-MCPD from CAC (2019), Philippine DOH-FDA, and FAO/WHO (2012) - International publications/ government websites for the ML of 3-MCPD in other countries (Australia, New Zealand, Canada, China, Korea, Singapore, Taiwan, and United States)	