Toxicology Reports 3 (2016) 544–551

Contents lists available at ScienceDirect

Toxicology Reports

journal homepage: www.elsevier.com/locate/toxrep

Food safety risk assessment for estimating dietary intake of sulfites in the Taiwanese population

Keng-Wen Lien[a], Dennis P.H. Hsieh[b], Hui-Ying Huang[c], Chiu-Hua Wu[d], Shih-Pei Ni[b], Min-Pei Ling[e,*]

[a] Institute of Food Science and Technology, National Taiwan University, Taipei, Taiwan
[b] Department of Health Risk Management, China Medical University, Taichung, Taiwan
[c] Department of Nutrition, China Medical University, Taichung, Taiwan
[d] Industrial Safety and Health Association, Hsinchu, Taiwan
[e] Department of Food Science, National Taiwan Ocean University, Keelung, Taiwan

ARTICLE INFO

Article history:
Received 25 April 2016
Accepted 9 June 2016
Available online 11 June 2016

Keywords:
Total diet study
Sulfur dioxide
Sulfites
Health risk
Risk assessment

ABSTRACT

The purpose of this study was to assess the health risk associated with dietary intake of sulfites for Taiwanese general consumers by conducting a total diet study (TDS). We evaluated the exposure of Taiwanese to sulfites in the diet and its associated health risk. This study used a list of 128 food items representing 83% of the total daily diet. Among the 128 food items, 59 items may contain sulfites. Samples of the 59 food items were collected and subjected to chemical analysis to determine the sulfur dioxide concentration. Health risk was assessed by calculating the ratio of exposure level to the acceptable daily intake (ADI) level of the analyte. For high-intake consumers, the HI of sulfites was 19.7% ADI for males over the age of three years at the 95th percentile; whereas for females over the age of 66, the HI was 17.8% ADI. The HI for high-intake consumers was above 10% ADI. This suggests that regulatory actions must be continued and that consumers should be advised to be aware of processed foods with relatively high contamination to avoid excessive exposure.

1. Introduction

The total diet study (TDS) has been used as a national monitoring research tool in assessing the associated health risk from dietary exposure to specific analytes [27,15,6]. TDS can be used to determine the levels of various contaminants and nutrients present in foods and to estimate public health risk due to chronic exposure to chemical substances [22]. They aim to estimate chronic risk to public health due to chemical substances. Approximately 33 countries, including Australia, New Zealand, Canada, China, France, Taiwan, The Netherlands, the United Kingdom, and the United States of America, have carried out TDS or TDS-like studies [7].

Sulfites are compounds that contain the sulfite ion ($SO_2{}^-$). Sulfur dioxide has been used since ancient times for its cleansing, disinfecting, and purifying properties. In addition, sulfites have a number of technological uses, for example, as antioxidant, bleaching agents, flour treatment agents, and preservatives. Sulfites are permitted in various foods such as wine, cordials, and dried fruit and vegetables. They are used in the food industry to maintain food color, to prolong shelf life, and to prevent microbial growth [11,19,37,34]. Sulfites are also used in the production of some food packaging materials and as processing aids for sterilizing bottles prior to packaging food or drink. Food is therefore a major source of sulfites. Sulfites may be present in food as sulfurous acid, inorganic sulfites, and other forms bound to the food matrix.

Sulfur dioxide used as a food additive in food for human consumption is generally recognized as safe when used in accordance with good manufacturing practice [35]. However, sulfites can trig-

Abbreviations: ADI, acceptable daily intake; ADD, average daily dose; BW, body weight; CAC, codex alimentarius commission; C, concentration; CR, consumption rate; COX-2, cyclooxygenase-2; EGF, epidermal growth factor; EGFR, epidermal growth factor receptor; EFSA, European Food Safety Authority; FAO, Food and Agriculture Organization; FSANZ, Food Standards Australia New Zealand; FSAI, food safety authority of Ireland; HI, hazard index; IARC, International Agency for Research on Cancer; ISO, International Organization for Standardization; JECFA, Joint FAO/WHO Expert Committee on Food Additives; LOD, limit of detection; LOQ, limit of quantitation; NOEL, no observed effect level; NAHSIT, nutrition and health survey in Taiwan; TFDA, Taiwan Food and Drug Administration; SCF, The Scientific Committee for Food; TDS, total diet study; ND, undetected; USFDA, US Food and Drug Administration; WHO, World Health Organization.

* Corresponding author at: Department of Food Science, National Taiwan Ocean University, 2, Bei-Ning Road, Keelung 20224, Taiwan.
E-mail address: mpling@mail.ntou.edu.tw (M.-P. Ling).

http://dx.doi.org/10.1016/j.toxrep.2016.06.003

ger asthma and other symptoms of allergic responses such as skin rashes and irritations in sulfite-sensitive people [39,9].

Sulfites were selected for evaluation in the 21st Australian TDS. FSANZ results show that the mean estimated dietary exposure to sulfites for all population groups is well below the acceptable daily intake (ADI). However, the 95th percentile of estimated dietary exposures to sulfites exceed the ADI for most population groups assessed, ranging from approximately 80% of the ADI for girls aged 13–18 years to approximately 280% of the ADI for boys aged two to five years [10]. The results of the 21st Australian TDS show a potential public health and safety concern for individuals with above-average consumption.

The Codex Committee on Food Additives and Contaminants and the Codex Committee on Contaminants in Food at its 38th session placed a dietary exposure assessment of sulfites on the priority list for evaluation by the [17].

Additives categorized under sulfites in the current Taiwan "Standards for Specification, Scope, Application and Limitation of Food Additives" list are sulfur dioxide, sodium sulfite, potassium sulfite, sodium sulfite (anhydrous), sodium metabisulfite, potassium bisulfite, and sodium bisulfite [31]. These sulfites are added to foods such as processed dried fruit, wine, beer, fruit, vegetable juices, drinks, processed fish, and seafood for the major purposes of preservation and inhibition of browning reactions [1,25,32].

Sulfur dioxide is traditionally used as an antioxidant and preservative in many foodstuffs. The TFDA surveys of commercially available foods found that the illegal use of preservatives and addition of bleaching agents is very common in Taiwan [29,18]. A local Taiwanese health bureau, for instance, analyzed sulfur dioxide from February to December in 2006. Among the 377 samples they collected, 15.1% tested positive for the bleaching agent sulfur dioxide. For example, zongzi (a glutinous rice dumpling wrapped in bamboo leaves), small dried shrimp, dried mushroom, and zongzi leaves have been found to contain more sulfur dioxide than what is allowed [38].

Sulfur dioxide is very often found to exceed permissible limits for their use. This problem not only poses a risk to public health, but also endangers the trade economy. Because of the growing concern on sulfur dioxide in processed food exceeding its ADI, we investigated sulfur dioxide concentrations and estimated the exposure of populations. As dietary composition and intake patterns in Taiwan are distinctly different from those in western countries where similar studies have been reported, the specific objectives of this study include the following:

(1) To determine the concentrations of sulfur dioxide in Taiwanese foods as consumed.
(2) To assess exposure of and risk to population groups of various ages.
(3) To identify which food items pose the greatest exposure risk to consumers.
(4) To provide recommendations for further follow up and monitoring of sulfur dioxide.

2. Materials and methods

2.1. Hazard identification

In a chronic-exposure experiment on three generations of animals that lasted nearly three years, rats were given drinking water with 750 ppm sulfur dioxide. Its report indicates no effect on growth, intake of food and fluid, fecal output, fertility, weight of the newborn, and frequency of tumor development [11]. In studies on long-term toxicity of sulfite via feeding and multigenerational studies in rats, metabisulfite levels of 1% and above led to pathological changes in the stomach [33]. Chronic overexposure to sulfur dioxide by inhalation may cause chronic bronchitis with emphysema and impaired pulmonary function [12,24]. Swallowing the liquid causes burns and tissue destruction of the esophagus and digestive tract, which may be fatal [23]. Sulfur dioxide could increase the expression of epidermal growth factor (EGF), epidermal growth factor receptor (EGFR), and cyclooxygenase-2 (COX-2) at transcription and translation levels in the lungs and tracheas in asthmatic rats. This increase might be one of the mechanisms by which sulfur dioxide pollution aggravates asthma [20]. The toxicity of the sulfites is generally low; evaluations by the Scientific Committee for Food (SCF) and by JECFA have led to the conclusion that for most consumers, sulfites in foods are of low health concern, although single, large oral doses of sulfites can produce gastrointestinal disturbances [28]. However, a small section of the population, mainly people suffering from asthma, responds to sulfites with allergy-like reactions. In sulfite-sensitive people, sulfites can provoke asthma and other symptoms of an allergic response such as skin rashes and irritations. Sensitivity to sulfites in food is dependent on how much a person is exposed to sulfur dioxide or sulfites from all sources. The pathogenesis of adverse reactions to sulfites has not been clearly documented but it is unlikely that sulfite reactions are allergic and immunity-mediated or produce anaphylactic reactions. Labeling of foods containing sulfite at concentrations of 10 mg/kg or more is required in the European Union, although the threshold for sensitivity reactions may be even lower [5].

An evaluation by the International Agency for Research on Cancer (IARC) shows that there is inadequate evidence of carcinogenicity of sulfur dioxide, sulfites, bisulfites, and metabisulfites in humans [13]. There is inadequate evidence for the carcinogenicity due to sulfites, bisulfites, and metabisulfites in experimental animals. The JECFA has established an ADI of 0–0.7 mg/kg body weight (BW)/day for sulfur dioxide JECFA, 2009. The no observed effect level (NOEL) that was established at the highest experimental dose at which no adverse effects were observed based on long-term (lifetime) studies in rats was 70 mg/kg BW/day. In establishing the ADI, a safety factor of 100 was applied to the NOEL to take into account species differences and individual human variation. The terms "sulfites" and "sulfating agents" usually refer to sulfur dioxide gas, sodium sulfite, potassium sulfite, and calcium sulfite, as well as hydrogen sulfites and metabisulfites. In this study, the concentration of sulfites in food is expressed as sulfur dioxide. Sulfur dioxide, sodium sulfite, potassium sulfite, bisulfites, and metabisulfites are collectively referred to as sulfites for the purposes of this study.

2.2. Core food list for the Taiwan TDS

Food consumption data from the 2005–2008 Nutrition and Health Survey in Taiwan (NAHSIT) are available [26]. The sample population consisted of 6189 participants randomly selected from 48 counties. Information on dietary intake was collected by two nonconsecutive, 24 h recalls in combination with a food frequency questionnaire. The preparation method for the core food list was the same as that used in our previous studies [21]. To construct the food list for the Taiwan TDS, 268,431 raw data entries were first obtained from 6104 questionnaires and then consolidated into 11,182 different food items that were grouped into 12 major categories and 47 subcategories on the basis of their nutrient content [3,2]. We selected 128 food items from the 47 subcategories to form a core list of food items to represent 83% of the total diet for Taiwanese individuals aged three and above.