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Original Article

# Investigation of aluminum content of imported candies and snack foods in Taiwan

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ABSTRACT

Candies, chewing gums, dried fruits, jellies, chocolate, and shredded squid pieces imported from 17 countries were surveyed for their aluminum content. The samples were bought from candy shops, supermarkets, and convenience stores, and through online shopping. Sample selection focused on imported candies and snacks. A total of 67 samples, including five chewing gums, seven dried fruits, 13 chocolates, two jellies, two dried squid pieces, and 38 candies, were analyzed. The content of aluminum was analyzed by inductively coupled plasma optical emission spectrometry (ICP OES). The limit of quantitation for aluminum was 1.53 mg/kg. The content of aluminum ranged from not detected (ND) to 828.9 mg/kg. The mean concentrations of aluminum in chewing gums, dried fruits, chocolate, jellies, dried squid pieces, and candies were 36.62 mg/kg, 300.06 mg/kg, 9.1 mg/kg, 2.3 mg/kg, 7.8 mg/kg, and 24.26 mg/kg, respectively. Some samples had relatively high aluminum content. The highest aluminum content of 828.9 mg/kg was found in dried papaya threads imported from Thailand. Candies imported from Thailand and Vietnam had aluminum contents of 265.7 mg/kg and 333.1 mg/kg, respectively. Exposure risk assessment based on data from the Taiwan National Food Consumption Database was employed to calculate the percent provisional tolerable weekly intake (%PTWI). The percent provisional tolerable weekly intake of aluminum for adults (19–50 years) and children (3–6 years) based on the consumption rate of the total population showed that candies and snacks did not contribute greatly to aluminum exposure. By contrast, in the exposure assessment based on the consumers-only consumption rate, the estimated values of weekly exposure to aluminum from dried papaya threads in adults (19–50 years) and children (3–6 years) were 4.18 mg/kg body weight (bw)/wk and 7.93 mg/kg bw/wk, respectively, for $50^{th}$ percentile consumers, and 6.26 mg/kg bw/wk and 12.88 mg/kg bw/wk, respectively, for $95^{th}$ percentile consumers.



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## 1. Introduction

Aluminum is the third most abundant element on earth. Aluminum additives are widely used in many food products such as flour, baking powder, firming agents, coloring agents, and anticaking agents. Food is the major source of aluminum exposure to humans [1]. Sedman [2] reported that aluminum intoxication was an iatrogenic disease and could cause encephalopathy, metabolic bone disease, and microcytic anemia. Excessive aluminum exposure to humans had been associated with adverse neurologic, hematopoietic, skeletal, respiratory, immunologic, and other health effects [3–5]. The European Food Safety Authority (EFSA) has established a tolerable weekly intake for aluminum, which is 1 mg aluminum/kg body weight (bw)/wk, and for highly exposed consumers the intake was estimated to be 2.3 mg/kg bw/wk [6]. In the 2011 Joint FAO/WHO Expert Committee on Food Additives (JECFA) report, the provisional tolerable weekly intake (PTWI) for aluminum was established to be 2 mg aluminum/kg bw/wk [7]. The dietary exposure estimates of children to aluminum-containing food additives could exceed the PTWI by up to twofold, according to the 2011 JECFA report. Codex [8] and EFSA regulated the maximum content of aluminum-containing additives in different specified food items to reduce the dietary exposure to aluminum. However, food additives containing aluminum were generally recognized as safe (GRAS) by the US Food and Drug Administration (FDA) when used as a salt substitute in accordance with good manufacturing practice. For foods more likely to be highly consumed by children, the Codex General Standard for Food Additive (GSFA) established the maximum permissible level of aluminum in various food category with added aluminum-containing additives as follows: 100 mg/kg in chewing gums, 100 mg/kg in crackers, 100 mg/kg in ordinary bakery products, 60 mg/kg in dairy-based drinks, 40 mg/kg in steamed breads and buns, and 40 mg/kg in mixes for bread and ordinary bakery wares [8]. The Commission Regulation (EU) No. 380/2012 permitted the maximum level of aluminum coming from all aluminum lakes to be up to 30 mg/kg in potato-, cereal-, flour-, or starch-based snacks; up to 70 mg/kg in confectioneries, and candied fruits and vegetables; up to 200 mg/kg, as aluminum sulfate, in candied cherries; and up to 300 mg/kg in chewing gums. In 2016, the Taiwan FDA specified the application scope and the maximum permissible level of food additives containing aluminum, including ammonium aluminum sulfate (INS523), aluminum potassium sulfate (INS 522), sodium aluminum sulfate (INS521), aluminum sulfate (INS520), and acidic sodium aluminum phosphate [INS541(i)]. These food additives have been restricted for use only in specified categories of food, with the maximum limits being 500 ppm in processed mollusks, crustaceans, and echinoderms products; 500 ppm in seaweed; 300 ppm in fried puffed foods; 300 ppm in pastries; 200 ppm in pickled vegetables; and 40 ppm in mixes for bread and ordinary bakery wares.

According to Sato et al [9], daily intakes of aluminum from sugar and confections/savories for younger children (1–6 years old) and children of 7–14 years of age in Japan were 0.83 mg/person/d and 0.7 mg/person/d, respectively. Only in small children the aluminum exposure for the percentages of 95$^{th}$ percentile (P95) to PTWI (2.0 mg/kg bw/wk) exceeded 100%, according to Sato et al [9]. Children are more susceptible to aluminum overexposure per kilogram of body weight than adults [6,7,10]. The study by Guo et al [11] found that children in China had the highest risk of aluminum exposure, with 22.8% having an aluminum intake higher than the JECFA PTWI. By contrast, only 3.2% of adults exceeded the PTWI in the same study.

The Taiwan FDA conducted a survey on aluminum content in domestic food products in 2012. The survey focused on aluminum-rich foods, including ordinary bakery products, fried puffed foods, pastry products, sugar-coated desserts, processed jelly fish products, mixes for bread and ordinary bakery wares, mung bean vermicelli, and cheese- and cocoa-based products. Previously, no surveillance and monitoring of aluminum content for imported candies and snack foods in Taiwan were carried out [12]; hence, a study to assess the dietary exposure of aluminum from candies and snack foods is very important.

## 2. Methods

### 2.1. *Reagents and chemicals*

Aluminum (1000 μg/mL, ISO Guide 34 Certified Reference Material) was obtained from High-Purity Standards (Charleston, SC, USA). Nitric acid (Selectipur-UPS, 70% purity) was obtained from BASF SE (Ludwigshafen, Germany). Hydrogen peroxide (Perdrogen 30% $H_2O_2$ (w/w), reag. ISO, reag. Ph. Eur. grade) was acquired from Sigma-Aldrich (St Louis, MO, USA).

### 2.2. *Equipment*

The high-speed pulverizing machine RT-02A was acquired from Rong Tsong Precision Technology Co. (Taichung City, Taiwan). The ASX-500 Series Auto Sampler was obtained from Agilent Technologies (Santa Clara, CA, USA) and the heating block BHW-09C from Kohan Instruments Co., Ltd. (Taipei, Taiwan). Microwave digestion of the sample was performed by CEM MARSXpress (CEM Corp., Matthews, NC, USA). Horiba Jobin Yvon-Ultima 2 inductively coupled plasma optical emission spectrometry (ICP OES) (HORIBA Jobin Yvon S.A.S., Longjumeau, France) was employed for the determination of aluminum.

### 2.3. *Sample collection and pretreatment*

The samples were bought from candy shops, supermarkets, and convenience stores, and through online shopping. Sample selection focused mainly on imported candies and snacks. A total of 67 samples, including five chewing gums, seven dried fruits, 13 chocolates, two jellies, two dried squid pieces, and 38 candies, were analyzed.

The samples were first cut into small pieces and homogenized using the high-speed pulverizing machine RT-02A. About 0.25 g homogenized sample was placed in a microwave digestion vessel, and 5 mL concentrated nitric acid was added. The temperature of the heating block was set at 105°C