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POSSIBLE HEALTH RISKS OF METAL RESIDUES IN DISPOSABLE CHOPSTICKS

Fwu-Ming Shen[1] , Hong-Wen Chen[2*] and Chun-Yu Chuang[3]

[1]Department of Biotechnology, Yuanpei University, 306 Yuanpei Street, Hsinchu 300, Taiwan, R.O.C

[2]Department of Environmental Engineering and Health, Yuanpei University, 306 Yuanpei Street, Hsinchu 300, Taiwan, R.O.C

[3]Department of Biomedical Engineering and Environmental Sciences, National Tsing Hua University, 101, Section 2, Kuang-Fu Road, Hsinchu 300, Taiwan, R.O.C

ABSTRACT

Taiwanese use over 30 billion pairs of disposable chopsticks every year. The heavy metal contamination of disposable chopsticks is a public health issue. Total heavy metal content of disposable chopsticks is 50.42 and 73.90 μg/g for a single pair and a coupled set, respectively. Manganese (Mn), zinc (Zn), and copper (Cu), in the order of abundance, are the three most common heavy metals found in chopsticks of both types. The hazard index of using a single pair and a coupled set are 1.322 and 1.681, respectively, suggesting that disposable chopsticks are likely to cause adverse human health effects and hazards. The policy of the Taiwan Environmental Protection Agency (EPA), made effective in 2007, curbs the use of disposable chopsticks in schools and government agencies and encourages the use of nondisposable stainless tableware. Monitoring the effectiveness of this policy and inspecting disposable chopsticks on the market should continue so as to ensure the health and safety of the public.

KEWORDS: disposable chopsticks, metals, residue, risk assessment, hazard index.

INTRODUCTION

Generally believed to have originated in ancient China, chopsticks are the traditional eating utensils of China, Japan, Korea, Taiwan, and Vietnam. They are a pair of small tapered sticks of the same length, commonly made of wood, bamboo, metal, bone, ivory, and in modern times, of plastic as well, and maneuvered in one hand – between the thumb and fingers – to pick up pieces of food.

Disposable chopsticks have health benefits, including the prevention of infections such as viral hepatitis and influenza. The Taiwan government encouraged the use of disposable chopsticks to effectively control viral hepatitis infection [1,2]. Disposable chopsticks are widely used in restaurants and homes. Since 2000, Taiwanese have been using over 30 billion pairs of disposable chopsticks annually [3]. However, disposable chopsticks are a waste of forest resources and cause other problems.

Disposable chopsticks are made of processed bamboo and wood. In the manufacturing process, bleach and artificial preservatives are used. Past studies showed that commercially made wood or bamboo disposable chopsticks release formaldehyde (0.10-0.31 mμg/ml) [4] and sulfur (0.1-0.5 g/kg) [3] and that 10-30% of them are contaminated with pathogenic E. coli [5]. In addition, trace elements, such as chromium, cadmium, lead, etc., are a concern. Chromium exposure produces acute overt symptoms as well as delayed manifestations including increase in the incidence of various human cancers [6]. An acute intake of cadmium causes necrosis and degeneration of the testes with complete loss of spermatozoa. Cadmium is also carcinogenic, and has been linked to lung and prostate cancer [7]. Lead is a physiologic and neurological toxin that can affect several organs and organ systems in the human body. Cadmium and lead can reduce cognitive development and intellectual performance in children and damage kidneys and the reproductive system [7,8]. Therefore, release of heavy metals from disposable chopsticks raises a public health issue.

This study has three aims: 1) to determine the concentration of each of 10 metal elements in disposable chopsticks (the common brands of Taiwan); 2) to determine the acidity (pH value) and release percentage leached from these disposable chopsticks in boiling water; 3) to assess the health risk from daily use of disposable chopsticks, and thereby provide reference values for the general public.

MATERIALS AND METHODS

Sampling

Two types of disposable chopsticks were selected for this study: single pair and coupled. Single pair chopsticks are two separate chopsticks, while coupled chopsticks refer to two chopsticks connected side-by-side at the top and need to be snapped apart when used. A total of 46 com-

TABLE 1 - Concentrations of heavy metals and essential trace elements in marketed disposable chopsticks (μg/g).

Elements	Single pairs (n=24)		Coupled sets (n=22)		*p* value	Correlation coefficient (*r*)
	Range	Mean	Range	Mean		
Al	0.03-1.43	0.78	0.06-1.58	0.72	NS	0.54
Cd	ND	ND	0.001-0.01	0.002	NS	0.21
Co	0.13-0.19	0.14	0.05-0.14	0.09	NS	0.52
Cr	ND	ND	0.001-0.02	0.006	NS	0.23
Cu	0.58-18.26	9.42	0.57-15.57	8.07	NS	0.86
Mn	2.65-65.14	33.89	2.29-107.42	59.12	<0.05	0.98
Ni	0.01-0.55	0.22	0.01-0.29	0.17	NS	0.41
Pb	0.001-0.12	0.04	0.002-1.06	0.31	<0.05	0.78
Zn	2.97-8.80	5.89	0.01-11.66	5.27	NS	0.32
Sn	0.01-0.14	0.04	0.01-0.32	0.14	<0.05	0.43
Total amount		50.42		73.90	<0.05	

TABLE 2 - Release percentage of heavy metals in the two types of disposable chopsticks.[a]

Elements	Single pairs (n=24)	Coupled sets (n=22)
	Release percentage (%)	Release percentage (%)
Al	20.21	19.56
Cd	5.48	5.63
Co	15.63	14.97
Cr	8.06	7.98
Cu	9.86	10.24
Mn	2.96	2.88
Ni	3.98	4.01
Pb	6.86	7.02
Zn	5.26	5.19
Sn	19.12	18.78

[a] Assayed using the modified daily usage method. the top end of chopsticks spiked with 50 μg/g metals is dipped in 100 ml of hot boiling water at 100℃ for and refluxed for one hour, in simulation to the way chopsticks are used to eating noodle or drink soup. Released rate and pH were detected after metals are leached from chopsticks.

mercially available disposable chopsticks were randomly selected and collected from 6 markets in Hsinchu. They included both imported (China, Vietnam) and locally (Taiwan) produced disposable chopsticks.

Pretreatment and analysis

The samples (3 g of dried disposable chopsticks) were refluxed in a glass bottle containing 40 mL of de-ioned water (100 ℃, 6 h). The supernatant was recovered by filtering through filter paper (Whatman no. 42). Contents of all elements were analyzed three separate times using a previously published mass spectrometry method [9-11] and a Perkin-Elmer 2100 Inductively Coupled Plasma Optical Emission Spectrometer. The operating conditions were as follows: 1) carrier gas (argon, 99.999%): 0.8 L/min; 2) plasma gas (argon, 99.999%): 13 L/min; 3) auxiliary gas (argon, 99.999%): 0.8 L/min; 4) pump rate: 1.5 mL/min; and 5) power: 1055 KW. The elements in samples were assayed using calibration curves based on standard series of stock solution dilutions of each element (1000 mg/L). The detection limits of elements were 0.07-1.4 μg/L.

Statistics

Content of each element and release rate from disposable chopsticks were measured. The analysis of variance (F) and Mann-Whitney U test were performed to compare the concentration differences between the two types of disposable chopsticks. Statistical analysis was performed using SPSS/PC+ (SPSS, Inc., Chicago, IL, USA). All differences were regarded as significant when $p < 0.05$.

RESULTS AND DISCUSSION

Concentrations of heavy metals

Table 1 shows the heavy metal concentration in market-available disposable chopsticks. Level of total heavy metals was lower in single pairs (50.42 μg/g) than in coupled sets (73.90 μg/g). Manganese (Mn; 30 μg/g), zinc (Zn), and copper (Cu), in the order of abundance, were the top three heavy metal contaminants in chopsticks of both types. Yet, Mn, Zn, and Cu concentrations were significantly higher in coupled sets than in single pairs. Moreover, there were no traces of either cadmium (Cd) or chromium (Cr) in single pairs, but coupled sets contained less than 0.01 μg/g. As correlation shown in the results, the presence of Mn, Cu, and Pb metals found in the two types of disposable chopsticks showed high values of coefficients, being 0.98, 0.86, and 0.78, respectively, compared with the presence of other metals, which are in the range between 0.21-0.54. The high value of coefficients indicated that there exists a consistency in the contamination with the two types of disposable chopsticks, and that the contamination is also related with the origin of production as well as the production process.

pH and metal release rate

pH and metal release rates are two other issues addressed in this study, since sulfuric acid is used as a disinfectant in the manufacture of disposable chopsticks. Consumer Reports of Taiwan in 2000 found 0.1-0.5 g/kg of SO2 in a sample of disposable chopsticks. Once dissolved, the sulfur dioxide becomes sulfuric acid and thus is likely to be a health concern in broth or soup solutions of high acidity. For this reason, to measure pH and the rate of metal release, the top end of chopsticks spiked with 50 μg/g metals is dipped in 100 ml of hot boiling water at 100℃ for and refluxed for one hour, in simulation to the way chopsticks are used to eat noodle or drink soup. Released rate and pH were detected after metals are leached from chopsticks. The measurement of pH, rather than acidity, is used in our study, as in common practice, to measure the acidity and alkalinity of solution, and pH measurement, as per IUPAC, is defined as:

$$pH = -\log_{10}\alpha_{H+} \approx -\log_{10}[H^+]$$

Where α_{H+} denotes the activity of H+ ions, and is dimensionless. The log10 denotes the base-10 logarithm, therefore pH defines a logarithmic scale of acidity.

Figure 1 is intended to show the pH measurement of the solution with hydrogen proton being dissolved into the broth after the use of disposable chopsticks of the two types. As shown in Figure 1, the average pH values of the solutions from using disposable chopsticks of coupled sets and single pairs are 4.15 and 4.80, respectively, while the blank solution, without the use of any disposable chopsticks, showed a pH value of 7.0, indicating that coupled set disposable chopsticks release more hydrogen proton that resulted in higher acidity in the solution, and, correspondingly, causing more health risk for human body. Moreover, Table 2 shows no significant difference in metal release rates between chopstick types. The release rates of Al, Sn, and Co were slightly higher (20, 19, and 15%, respectively) than the release rates of Cr, Cu, and Zn (5~10%), and lowest for Mn (3%) and Ni (4%).

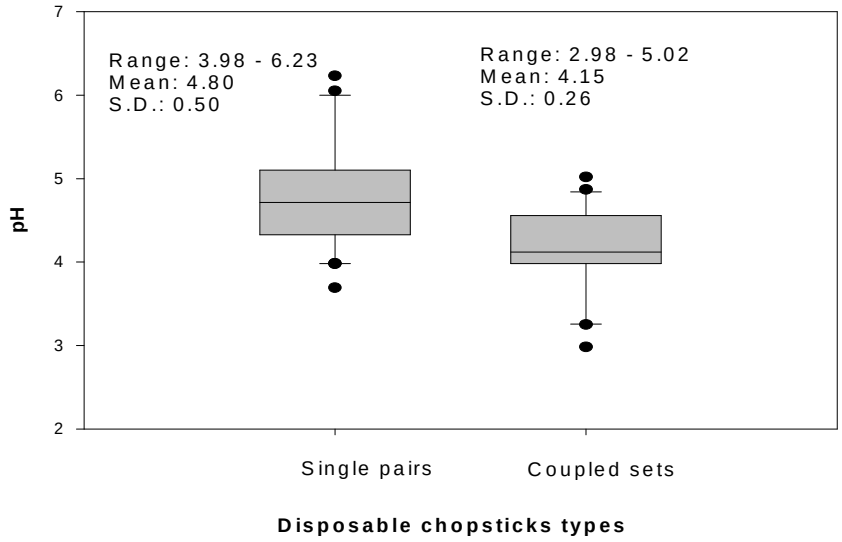

FIGURE 1 - pH of two types of disposable chopsticks. The pH was measured in the top ends of the chopsticks, which are normally used by the general public in daily life.

TABLE 3 - Assessment of non-carcinogenic health risk attributable to intake of heavy metals from usage of disposable chopsticks (mg/kg-day).[a]

Heavy metals	RfD (mg/kg-day)	Hazard quotient (HQ)	
		Single pairs	Coupled sets
Cr	3×10^{-3}	0	0.003
Cd	1×10^{-3}	0	0.005
Cu	4.3×10^{-2}	0.661	0.588
Mn	5×10^{-2}	0.614	1.042
Ni	2×10^{-2}	0.015	0.012
Pb	1.43×10^{-3}	0.000	0.002
Zn	3×10^{-1}	0.032	0.028
Hazard index (HI= ΣHQ)		1.322	1.681

[a]Hazardous Index method.

Risk assessment

The large annual consumption of disposable chopsticks in Taiwan may have a measurable impact on health. To assess this impact, we calculated the Hazard Quotient (HQ), which is the heavy metal intake (dose) divided by the recommended reference dose (RfD) as per the US EPA's IRIS standards, and the Hazard Index (HI) [12], which is the sum of all HQs, with HI<1 indicating no risk of adverse health effects, and HI>1 indicating moderate risk of adverse health effects. These calculations are as shown in Formulae 1 through 3, where RfD is the recommended reference dose, Ci is the average metal concentration assayed in the broth of boiled disposable chopsticks (in μg/g), Ti is the number of times disposable chopsticks were used per day (e.g., 3 times), Ri is the percentage of metal release (e.g., Al, 20.21%), Ed is the years of exposure to disposable chopsticks (e.g., 50 years), Bw is average body weight (e.g., 70 kgs), and At is average life expectancy (e.g., 70 years).

$$Hazard\ Quotient = \frac{Exposure\ Dose}{RfD} \quad \text{.....(1)}$$

$$Exposure\ Dose = \frac{Ci \times \mathrm{R}i \times \mathrm{T}i \times \mathrm{E}d}{Bw \times At} \quad \text{.....(2)}$$

$$Hazard\ Index = \sum_{n=1}^{n=k} Hazard\ Quotient \quad \text{.....(3)}$$

Table 3 shows that the health hazard index of using single pairs and coupled sets of disposable chopsticks, calculated as above, is 1.322 and 1.681, respectively. Adverse effects are implied by both values being greater than 1.0. Of all the elements tested in this study, manganese (a brittle metal, abundant in the earth's crust, soil, and sedimentary rocks, and commonly used in the manufacture of ferrous alloys and steels) has the highest health quotient and therefore is the largest contributor to health hazard. Lucchini et al. (2007) [13] found that exposure to manganese results in pathological changes in the nervous system and induction of Parkinson disease. Moreover, Li et al. (2004) [14] found that manganese exposure induces oxidative stress, inhibiting macrophage cell function in the lungs. The fact that over 80% of the disposable chopsticks used in Taiwan are imported from China and Vietnam may explain their high concentration of manganese, which is likely to come from contaminated soils or steel mill waste.

CONCLUSIONS

We showed that disposable chopsticks contain hazardous amounts of heavy metals; these findings should alert authorities to this health hazard, and to the need for further studies. Additionally, the disposal of 30 billion pairs of chopsticks each year is an environmental problem involving not only accumulation of trash, but also the annual felling of 3 million trees, aggravating the problems of global warming. EPA's policy made effective in 2007, the use of disposable chopsticks in schools and government agencies and promoting the use of non-disposable stainless tableware. To ensure public health, the effectiveness of this policy should be monitored, while continuing to inspect commercially available disposable chopsticks. As our study was conducted over a short time only, the data we collected may be limited in terms of temporal generality, and, for a further project, we are planning to cover a longer time and large samples, in order to collect adequate information and data to make to accurately evaluate possible health risks of metals residues in disposable chopsticks.

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CORRESPONDING AUTHOR

Hong-Wen Chen
Yuanpei University
Department of Environmental
Engineering and Health
306 Yuanpei Street
Hsinchu 300
TAIWAN, R.O.C

Phone: +886-3-5381183 ext.8538
Fax: +886-3-5385353
E-mail: hwchen@mail.ypu.edu.tw

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