Survey and exposure estimates of cadmium in desert lettuce

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Introduction

Food safety issues are of growing concern to consumers. Both microbial and inorganic contaminants are of concern in fresh fruits vegetables. This concern over inorganic contaminants is exemplified by recent publicity over the small levels of perchlorate in the Colorado River and accumulation by crops irrigated with this water. Recently, we conducted survey work for perchlorate in lettuce and we found potential perchlorate exposure from lettuce was negligible relative to harmful amounts. By developing this information we successfully avoided a food safety scare that might have had an adverse economic impact on local produce industries.

Heavy metals exists as contaminants in irrigation water, soil, and fertilizers or amendments are potential future issues. Cadmium (Cd) is a natural contaminant in some soils and in most phosphate fertilizers. The amounts of Cd in phosphate rocks varies by source, ranging from 3 to 15 mg/kg in phosphate mined in Florida to as high as 130 mg/kg in phosphate rock mined in the western United States (Mortvedt et al., 1981). Most of the Cd in phosphate rock remains in the P fertilizers after processing. Lettuce requires large applications of P fertilizer for optimal yield and quality and has a propensity to accumulate heavy metals. A number of studies have shown lettuce accumulates Cd when exposed to natural and anthropogenic sources.

Food is the major source of Cd exposure to humans (Gartrell et al., 1986; Gunderson, 1995; Pennington et al., 1986) and vegetables generally account for 40% the daily intake of Cd. The World Health Organization (WHO) has established a provisional daily intake of cadmium at 1 ug/kg body weight (Walker and Herman, 2000). The FAO and WHO established the Codex Committee for Food Additives and Contaminates (CCFAC) to address food safety issues and legislation. Based on consumption estimates and cumulative exposure projections, the CCFAC has recommended maximum levels (MLs) for various food commodities. The European Union (EU) has incorporated many of the criteria used by the CCFAC and have actually adapted many of the proposed MLs. For example, the ML for fruit, rooting vegetables, wheat, and lettuce are 50, 100, 200, and 200 ug/kg, respectively (Berg and Licht, 2002).

These MLs are largely based on extrapolations from toxicological evidence from rice consuming populations affected with Cd induced renal proximal tubular dysfunction (Kobayashi 1978; Cai et al., 1995; Kobayahi et al., 2000). However, these estimates ignore differences in metal antagonist among various food sources and differences in the nutritional status of different populations (Chaney et al., 2004). For example, rice is low in zinc (Zn), iron (Fe), and calcium (Ca). High concentrations of one or more of these elements reduce the rate of Cd absorption in to the bodies of test animals and humans (Flannagan et al., 1978; Fox, 1988; Reeves and Chaney, 2002; Reeves and Chaney, 2004). Little consideration has been given to nutritional factors affecting the bioavailability of Cd.

Buyers from the EU have scrutinized durum wheat produced in our desert region for Cd content and Arizona wheat shippers have had to modify culture and handling practices in attempts to comply with EU concerns. It is likely that Cd policy for vegetable crops developed by the WHO and the EU will eventually influence Cd policy in Canada and the United States. The objective of this proposed study is to conduct survey work and estimate exposure estimates for Cd in lettuce. We will also measure lettuce Zn, Fe, and Ca concentrations to compile a data base that may be relevant in future risk assessment evaluations.

Approach

Lettuce samples were collected across the low desert production area, were freeze-dried, ground, and are in storage. These samples were digested using a nitric acid/peroxide digest and analyzed for Cd, Zn, Fe, and Ca by inductively coupled plasma/mass spectroscopy (ICP/MS).

Results

The range, mean, median, and 90^{th}% levels of cadmium (Cd), zinc (Zn), iron (Fe), and calcium (Ca) in desert lettuce are shown Table 1. For, iceberg, romaine, Boston, and green leaf lettuce types, Cd levels were always below the ML of 200 ug/kg set by the EU. For red leaf there was the occasional sample with concentrations of Cd above this ML but the mean, median, and 90^{th}% levels, were below the ML.

Another way to assess potential risk is to consider hypothetical exposure relative to established references dosages. Mean and 90^{th}% estimates of lettuce consumption have been reported at 46 and 137 g per day for adult males (Smiciklas-Wright, 2002). From these values we can estimate dosages of Cd and compare them to the established oral reference dosage (RfD) of 1 ug/kg day (Figure 1). From this figure we can see that mean exposures are always less than 10% the RfD and 90^{th}% exposures are less than 22% the RfD.

The concentrations of Cd in lettuce types produced outside the low desert are shown in Table 2. Although there seemed to be differences among the areas outside the low desert, we did not have sufficient data for meaningful statistical comparisons across these areas. Overall, the ranges in Cd concentrations across all lettuce producing areas outside the low desert region are similar to those in the low desert.

It has been noted that Zn, Fe, and Ca affect the Cd absorption by mammals. The ratios in of these cations to Cd within and outside the low desert are shown in Tables 3 and 4, respectively. Although the ratios seem large, we do not have the data at this time to assess what impact these cations have on the bioavailability of Cd to mammals.

Overall, these data indicate Cd exposures from lettuce produced in the desert generally would not exceed that from lettuce produced in other regions. Finally, these data show that the Cd concentrations in desert lettuce are well below levels considered safe from established risk assessment evaluations.

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Table 1. Content of cadmium, zinc, iron, and calcium in the edible portions of lettuce produced in the low desert of the southwestern United States.

Type		Cadmium (µg/kg fresh weight)			
	n	Range	Mean	Median	90th%
Iceberg	24	20-86	48	46	68
Romaine	24	24-128	72	70	105
Boston	24	50-140	90	84	126
Green leaf	24	64-174	88	79	119
Red leaf	24	69-239	118	113	176
		Zinc (µg/kg fresh weight)			
Iceberg	24	1261-3947	1861	1673	2484
Romaine	24	1249-2885	2164	2164	2710
Boston	24	1580-2852	2158	2152	2597
Green leaf	24	994-4221	2243	2067	2920
Red leaf	24	1700-4461	2558	2336	3461
		Iron (mg/kg fresh weight)			
Iceberg	24	2.3-30.3	8.7	6.9	12.4
Romaine	24	3.4-37.1	13.0	10.1	20.6
Boston	24	3.7-134.9	54.7	57.8	95.8
Green leaf	24	12.3-97.0	50.3	55.5	83.0
Red leaf	24	15.5-129.5	51.8	50.7	73.6
		Calcium (mg/kg fresh weight)			
Iceberg	24	152-434	232	220	290
Romaine	24	215-750	428	424	617
Boston	24	297-912	555	532	720
Green leaf	24	347-826	626	626	808
Red leaf	24	451-1564	772	681	1179

Table 2. Ranges of cadmium, zinc, iron, and calcium in lettuce samples collected from production areas outside the low desert region.

Type	n	Cadmium (µg/kg fresh weight)
Iceberg	9	8-50
Romaine	8	13-139
Boston	5	19-175
Green leaf	9	9-204
Red leaf	9	9-111
		Zinc (µg/kg fresh weight)
Iceberg	9	559-2861
Romaine	8	824-3309
Boston	5	1546-7694
Green leaf	9	1823-5583
Red leaf	9	1758-7046
		Iron (mg/kg fresh weight)
Iceberg	9	2.3-12.2
Romaine	8	6.1-58.6
Boston	5	9.7-92.2
Green leaf	9	6.5-143.4
Red leaf	9	19.1-191.4
		Calcium (mg/kg fresh weight)
Iceberg	9	123-565
Romaine	8	202-669
Boston	5	303-1114
Green leaf	9	283-1106
Red leaf	9	279-1274

These include a random selection of a subset of samples collected in lettuce production areas outside the low desert region, including California, New Mexico, Colorado, Michigan, Ohio, New York, New Jersey, and Quebec.

Table 3. Ranges of ratios of zinc, iron, and calcium to cadmium in the edible portion of lettuce produced in the low desert region of the southwestern United States.

Type			
	Zn/Cd	Fe/Cd	Ca/Cd
Iceberg	22-76	53-358	2480-9908
Romaine	18-80	54-682	3409-13,161
Boston	14-57	32-1268	3842-9216
Green leaf	10-58	182-1305	4413-11,692
Red leaf	7-32	120-1157	3777-11,726

Table 4. Ranges of ratios of zinc, iron, and calcium to cadmium in the edible portion of lettuce from productions areas outside the low desert region.

	Zn/Cd	Fe/Cd	Ca/Cd
Iceberg	28-146	46-558	2727-30,865
Romaine	6-157	108-2865	2767-32,675
Boston	9-160	142-1937	3462-35,511
Green leaf	13-211	149-5659	2277-62,265
Red leaf	49-201	557-5065	6104-38,891

These include a random selection of a subset of samples collected in lettuce production areas outside the low desert region, including California, New Mexico, Colorado, Michigan, Ohio, New York, New Jersey, and Quebec.

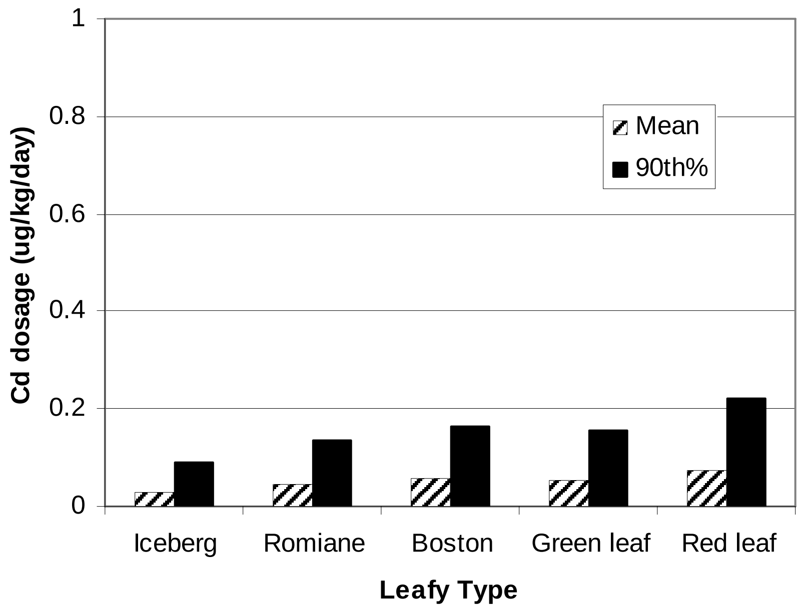

Figure 1. Mean and 90th% Cd adult males dosages for five lettuce types relative to the RfD of 1 ug/kg/day.