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EVALUATION OF STAGE 2 BABY FOODS AS POTENTIAL SOURCE OF HEAVY METAL TOXICITY IN INFANTS 6 TO 12 MONTHS

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Abstract

The levels of cadmium (Cd), lead (Pb), mercury (Hg), and arsenic (As) in Stage 2, thick puree non-meat containing, infant foods (6 to 12 months) available for purchase in commercial supermarkets and "Big Box" stores in the US were determined by microwave digestion and ICP-MS analysis. We sampled 132 products from five brands labeled certified organic and five brands labeled natural. Overall, only six samples had one of these four heavy metals measure outside of the established European Union 50 ng/g limit for heavy metals in cereal, fruit, vegetables. There were no samples with two or more metals above the set limit. These results indicate that infants transitioning from breast milk or formula to solid foods would not increase their exposure to heavy metal toxins when consuming Stage 2 baby food products sold in the United States.

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Introduction

Heavy metals such as cadmium (Cd), lead (Pb), mercury (Hg), and arsenic (As) have no known functionality or nutritional value within the human body. In contrast, these metals have many industrial uses from electroplating and batteries to components of printed circuit boards used in modern electronics. Their presence within the human body is due to exposure to sources such as ground water, forest fire and volcanic ash, natural erosion, factory and power plant emissions, regulated release by industry into natural water ways and unregulated pollution.[1-3] Consequentially, these elements are found in detectable quantities in all commercially available food products, including products marketed as baby foods. Elevated levels of these elements have been shown to cause neurological disorders, cancers, and other serious health related issues. Infants with their small mass and developing systems are especially sensitive to the even low levels of these contaminants. Exposure for infants is higher than for adults, primarily due to the greater amount of food consumed in relation to body weight. Excessive exposure in infants to these heavy metals has been shown to cause delays in cognitive, motor, and auditory development.[4-10]

Experts consider cereals, produce (fruits and vegatables) and tap water contribute the most dietary exposure to heavy metals but there is very little guidance on what levels are considered safe for infants in the 6 to 12 months age range.[11] The Food and Drug Administration (FDA) has issued a limited guidance on heavy metal concentrations in food products consumed by infants and children. The guidance level for lead in was set at 100 ng/g for candy and 50 ng/g for juice. The guidance levels for arsenic was set at 100 ng/g for rice cereal and 10 ng/g for apple juice.[12-15] The FDA has not established a guidance level for cadmium and the guidance levels for mercury pertain to fish and fish products. The European Union (EU) has done more extensive research maximum levels for certain heavy metal contaminants in food products.[16] Lead and cadmium are regulated from 50 ng/g to 200 ng/g in foods such as cereals, fruit, and vegetables, but not specifically baby food. Infant formula has a 20 ng/g limit for lead and a 5-20 ng/g limit for cadmium based on the protein source. Mercury is again limited to fish products and there are no specific levels for arsenic.

The purpose of this study was to evaluate the potential for toxic exposure from Pb, Cd, Hg, and As in infants as they transition from breast milk or formula to solid foods during their first 6 to 12 months of development.

Experimental

Baby Food Samples

One hundred and thirty two individual Stage 2 baby food products were purchased from local supermarkets and "Big Box' stores from 10 commercial brands. Five brands (71 products) were labeled "Organic", brands that create their products with ingredients grown using organic farming practices, and five brands (61 products) labeled "Natural", brands that make their products with ingredients produced using standard farming practices. All products were packaged in either 4 oz plastic tubs, jars or pouches. The products were either a single type of fruit or vegetable or a mixture of 2 or 3 items from the following list: Carrots, Strawberries, Chickpeas, Apples, Blueberries, Oats, Purple Carrots, Bananas Avocados, Quinoa, Sweet Potatoes, Papaya, Kale, Granola, Guavas, Beets, Pears, Spinach, Green Beans, Passion Fruit, Grapes, Cucumber, Peas, Raspberries, Butternut Squash, Cauliflower, Oatmeal, and Figs. All samples were analyzed as purchased for consumption.

Reagents

Reagent grade nitric acid was purchased from Fisher Scientific (Pittsburgh, PA), and purified on-site using a sub-boiling distillation system (Milestone Inc, Monroe Ct.). De-ionized water was purified with a Milli-Q (Millipore, Billerica, MA) Type 1 purification system and used to prepare all samples and calibration solutions. The 100 µg/ml multi-element solution, used to prepare the ICP-MS calibration standards, and a 1000 µg/mL Au solution, used to stabilize Hg, were purchased from Fisher Scientific (Pittsburgh, PA).

Instrumentation

Microwave Digestion System

Samples for this study were prepared using an Ethos Plus Microwave Labstation (Milestone Inc, Monroe CT). This system consists of the microwave unit, a 10 position high pressure (1500 psi) segmented rotor, temperature and pressure control, and high purity quartz inserts. EasyWAVE software was used to monitor and control the microwave power and temperature. This software uses sophisticated process algorithms, which ensure precise process control through microwave power regulation.

Inductively Coupled Plasma Mass Spectrometer (ICP-MS)

An Agilent Technologies (Santa Clara, CA) 7500ce ICP-MS equipped with an octopole collision cell and autosampler was used to determine heavy metal concentrations in the microwave digested tattoo inks using the operating conditions in Table 1. The Agilent ICP-MS system allows for the analysis of elements normally affected by plasma-based polyatomic interferences, by adding gasses (helium or hydrogen), to a collision cell. The added gas molecules collide or react with a polyatomic species to effectively remove it from the ion stream. Helium collision mode was used for this work. The internal standards were added to each sample during aspiration, via a mixing tee, before entering the nebulizer.

Methods

Instrument Calibration and Method Limit of Quantitation

The 100 µg/ml multi-element solution, was diluted to prepare a series of calibration solutions ranging from 0.250 ng/mL to 20 ng/mL. Each calibration solution contained 1% (v/v) HNO_3 and 200 ppb Au for matrix matching and solution stabilization. The instrument detection limit (IDL) was calculated as three times the standard deviation of 10 blanks divided by the slope of the elemental calibration line. The method detection limit (MDL) was calculated by multiplying the IDL by the analysis dilution factor then dividing by the average sample weight of 4.00 grams. Table 2 lists the calibration curve, IDL and MDL information for each element in this study.

ICP-MS Sample Preparation[17,18]

Each baby product was analyzed as received and homogenized by thoroughly mixing before analysis. 3.5 to 4.5 grams of baby food product was weighed directly into a quartz insert. After weighing was complete, 5 mL of concentrated sub-boiled HNO_3 was added to the quartz insert. The quartz insert was then placed into the Teflon microwave vessel containing 10 mL of DI water. The vessel was capped, then microwave heated using a 10 minute ramp to 180°C and held at temperature for 10 minutes. When the microwave-heating program was complete, the microwave vessel was removed and allowed to cool. Upon cooling, the contents of the quartz insert were transferred into a 50 mL polypropylene centrifuge tube. 1 mL of 50 µg/mL Au solution was added to stabilize Hg for the ICP-MS analysis and the digestate was diluted to 50 mL with DI water. Prior to ICP-MS analysis the samples were diluted 10 fold with DI water to matrix match calibration standards.

Table 1. Operating Conditions of the Agilent 7500ce ICP-MS

Parameter	Setting
RF Power	1500W
Plasma gas flow rate	13.0 L/min
Auxiliary gas flow rate	1.0 L/min
Carrier gas flow rate	0.99 L/min
Makeup gas flow rate	0.10 L/min
Collision gas flow rate	5 ml/min
Nebulizer	Meinhard Concentric
Isotopes Measured	Cr^{53} As^{75} Cd^{111} Hg^{202} Pb^{208}
Internal Standards	Sc^{45} Y^{89} In^{115} Bi^{209}

Results and Discussion

The challenging part about this study was determining the best way to present the results in a meaningful format which will allow us to come to some basic conclusions about heavy metal exposure from the baby foods involved in this study. We felt the best way was to provide the big picture then subdivide by product. When presenting the results, we chose concentration ranges reflective of the current guidance limits from the FDA and EU, and then tabulated the number of samples within each range. Table 3 presents the cumulative results from all 132 samples. For As, 85% of the samples tested were below the 10 ng/g the FDA apple juice limit and 100% of the sample were below the 100 ng/g rice cereal limit. For Cd, 79% of the samples were below the 20 ng/g EU infant formula limit and 98% were below the 50 ng/g EU cereal, fruit, and vegetable limit. For Hg, 89% of the samples were below 10 ng/g and the remaining 11% were on average less than 25 ng/g. For Pb, 90% of the samples were below the 20 ng/g EU limit for infant formula and 98% were below the 50 ng/g EU cereal, fruit, vegetable limit. One sample did express a large lead concentration of 554 ng/g, 10 times the recommended limit. Overall, only six samples (4.5%) had one tested heavy metals measure outside of the established limits. No samples had two or more of the tested heavy metals measure outside of the set limits.

We then broke the results down by brand to see if there were

Table 2. ICP-MS calibration equations, instrumental and method detection limits.

Isotope	Mode	Equation	R^2	IDL (ng/mL)	MDL (ng/g)
Cr^{53}	He	y = 833x +52	0.9998	0.066	8.24
As^{75}	He	y = 542x +13	0.9999	0.015	1.83
Cd^{111}	Normal	y =14940x + 630	0.9999	0.051	6.37
Hg^{202}	Normal	y = 5960x - 391	0.9990	0.079	9.95
Pb^{208}	Normal	y = 14964x +352	0.9995	0.039	4.87

Table 3. Cumulative summary of all samples analyzed in this study.

Measured Concentration (ng/g)	As		Cd		Hg		Pb	
	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)
≤MDL	61		64		117		59	
≤10	51	4.95	19	8.16			25	7.5
10 > to ≤ 30	18	15.0	21	16.7	15	24.2	36	19.6
30 > to ≤ 50			25	37.5			9	38.6
50 > to ≤ 100			3	57.2			2	67.8
>100							1	554

Table 4. Summary results from Brand 1 labeled certified organic.

Measured Concentration (ng/g)	As		Cd		Hg		Pb	
	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)
≤MDL	2		7		9		9	
≤10	6	4.31	2	7.5			1	9.8
10 > to ≤ 30	4	11.3	2	11.4	3	21.2	1	18.44
30 > to ≤ 50			1	31.6				
50 > to ≤ 100								
>100							1	554

Table 5. Summary results from Brand 2 labeled certified organic.

Measured Concentration (ng/g)	As		Cd		Hg		Pb	
	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)
≤MDL	4		6		11		2	
≤10	7	4.94					6	7.65
10 > to ≤ 30	1	11.1	4	16.7	1	22.2	3	19.4
30 > to ≤ 50			2	31.1			1	47.7
50 > to ≤ 100								
>100								

Table 6. Summary results from Brand 3 labeled certified organic.

Measured Concentration (ng/g)	As		Cd		Hg		Pb	
	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)
≤MDL	4		2		7		2	
≤10	2	6.01	1	8.64			3	6.40
10 > to ≤ 30	1	19.3	3	20.2			1	13.5
30 > to ≤ 50			1	32.2			1	39.9
50 > to ≤ 100								
>100								

Table 7. Summary results from Brand 4 labeled certified organic.

Measured Concentration (ng/g)	As		Cd		Hg		Pb	
	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)
≤MDL	4		6		12		5	
≤10	3	2.32	3	8.07			0	
10 > to ≤ 30	6	15.5	1	14.3	1	24.5	6	15.3
30 > to ≤ 50			3	33.1			1	46.1
50 > to ≤ 100							1	60.4
>100								

Table 8. Summary results from Brand 5 labeled certified organic.

Measured Concentration (ng/g)	As		Cd		Hg		Pb	
	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)
≤MDL	9		11		18		13	
≤10	14	4.62	7	8.07			5	6.79
10 > to ≤ 30	4	17.9	7	14.7	9	23.29	6	20.9
30 > to ≤ 50			2	32.5			3	35.8
50 > to ≤ 100								
>100								

Table 9. Summary results from Brand 6 labeled natural.

Measured Concentration (ng/g)	As		Cd		Hg		Pb	
	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)
≤MDL	22		11		27		9	
≤10	5	3.59	2	8.11			3	6.78
10 > to ≤ 30			2	17.8			12	21.43
30 > to ≤ 50			11	44.9			2	33.7
50 > to ≤ 100							1	67.2
>100								

Table 10. Summary results from Brand 7 labeled natural.

Measured Concentration (ng/g)	As		Cd		Hg		Pb	
	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)
≤MDL	8		9		13		8	
≤10	5	4.76					2	9.91
10 > to ≤ 30							2	20.1
30 > to ≤ 50			2	35.6			1	31.1
50 > to ≤ 100			2	60.0				
>100								

Table 11. Summary results from Brand 8 labeled natural.

Measured Concentration (ng/g)	As		Cd		Hg		Pb	
	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)
≤MDL	6		6		10		5	
≤10	4	3.30					2	8.38
10 > to ≤ 30			2	22.1			3	15.3
30 > to ≤ 50			2	39.7				
50 > to ≤ 100								
>100								

Table 12. Summary results from Brand 9 labeled natural.

Measured Concentration (ng/g)	As		Cd		Hg		Pb	
	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)
≤MDL			1		2		2	
≤10	1	5.32	2	8.64				
10 > to ≤ 30	2	14.4			1	21.1	1	13.5
30 > to ≤ 50								
50 > to ≤ 100								
>100								

Table 13. Summary results from Brand 10 labeled natural.

Measured Concentration (ng/g)	As		Cd		Hg		Pb	
	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)	Number of Samples	Avg. (ng/g)
≤MDL	4		5		8		4	
≤10	4	5.63	2	8.8			3	5.53
10 > to ≤ 30							1	22.3
30 > to ≤ 50			1	35.6				
50 > to ≤ 100								
>100								

any underlying trends. Tables 4 to 8 report the results from the brands labeled 'certified organic' and Tables 9 to 13 report the results from the brands labeled 'natural'. The organic brands did not contain significantly lower concentrations of heavy metals that the natural brands. It was surprising to see that the 554 ng/g Pb spike was from a sample that was labeled 'certified organic'.

Conclusion

According to the American Academy of Pediatrics infants between 6 and 12 months of age should be eating about 4 ounces (113g) of solids and 6-8 ounces (180 to 240 mL) of breast milk or formula at each of their meals (breakfast, snack, lunch, snack, dinner).[19,20] Based on the breast milk concentrations of Pb, Hg, and Cd reported in previous studies from a number of countries (0.5 to 126.55 ng/g for Pb, 0.64 to 257.1 ng/g, for Hg and 0.05 to 24.6 ng/g Cd, 0.5 to 8.9 ng/g for As)[21-23] infants following the recommend feeding guidelines would not significantly increase their exposure to heavy metal toxins when transitioning to Stage 2 food products sold in the United States.

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