Lead Contamination in Domestic and Foreign Chocolate Products

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Abstract

This study was performed to compare the levels of lead contaminants in foreign and domestic chocolates. Chocolate samples were collected from four of the leading chocolate manufacturers in the world. These manufacturers include Hershey and Mars chocolate from the United States, Lindt and Sprungli company from Switzerland, and Royce’ chocolate from Japan. Two samples from each company, milk and dark chocolate, were analyzed using the cocoa producers’ alliance protocol and atomic absorbance spectroscopy. These results were compared to the FDA guidelines; every manufacturer had chocolates measuring below the accepted levels of lead contamination in chocolate. However, the Mars dark chocolate from the US measured the highest for lead contaminants with 0.09 ppm, the lowest levels of lead were found in the Mars milk chocolate, which contained only 0.003 ppm.

Introduction

Lead contamination in candies has been recognized as a health problem since the 1800’s (Acum 1820). Since that time lead contamination has been reported in paints, children’s toys (Holstege 2008), in foods, and calcium supplements (Scelfo et al 2000).

Lead poisoning has many physiological effects including neurological damage to brain neurons resulting in encephalopathy. Lead is known to compete with calcium ions for transport systems on membrane thereby effecting protein channel functions and neurotransmitter release. Effects are especially severe for children with blood lead levels (BLL) of 10 mcg/dL (0.1 ppm) or more (Holstege 2008). Children are more susceptible to lead poisoning due to the fact
that their body systems, including brain and gastrointestinal tracts, are still developing. This causes them to be more prone to lead absorption compared to adults.

Lead contamination also affects cardiovascular function and reproduction. Lead is an inorganic substance that, when it enters the body, can bind to biological molecules. Lead decreases heme biosynthesis by inhibiting aminolevulinic acid dehydratase and ferrochelatase activity (Holstege 2008). These enzymes play an important role in adding iron to protoporphyrins and metabolizing them into heme in the red blood cells. This effect of lead causes the increase in free erythrocyte protoporphyrins in the blood as well as aminolevulinic acid levels (ASTDR 2007). This can decrease pH in the blood and affect oxygen distribution in the blood and tissues. The Environmental Protection Agency (EPA) has reported the threshold BLL for decreased hemoglobin to be 50 mcg/dL (0.5 ppm) in adults and as low as 25 mcg/dL (0.25 ppm) in children (1986).

One potentially significant source of lead in a child’s diet is chocolate products (Rankin et al 2005). America consumed about 1.5 million tons of chocolate in 2003 and 2004. Chocolate consumption is increasing by 3.7% a year (ICCO, 2007). According to a study by Rankin et al (2005), traces of lead were routinely found in chocolate
products and cocoa beans. Lead is a naturally-occurring substance that enters food through the environment. This contamination poses a public health problem, especially in older individuals and children (Mushak and Crocetti 1990).

Traces of lead are found in chocolate as a result of the soil cocoa beans are grown in. Some of these areas where chocolate is grown are South America, India and Africa. Fertilizer, pesticides and lead based fuel, are all possible sources of lead contamination. However, the levels of lead in cocoa beans from the plants are low compared to traces of lead in the final chocolate products (Rankin 2005). This suggests that most of the lead contamination in chocolates occur during processing of confectionery products. The U.S. Food and Drug Administration (FDA) has issued a recommended limitation of 0.1 ppm (parts per million) of lead allowed in chocolate and other candies (FDA 2005); however, the compliance of chocolate confectioneries to this FDA ruling is optional. This limit may be compared to the limit for contamination in drinking water set by the EPA, which is set at 0.015 ppm (2008).

The Food and Drug administration tested various cocoa products and discovered some chocolates to be over the recommended 0.1 ppm standard (FDA 2006). Data from India revealed the levels of lead in
the chocolate candies to be as high as 8.04 micrograms of lead per gram of chocolate, which is eighty times more than the recommended limit (Dahiya et al 2004). The objective of this study was to compare the chocolate products of three manufacturers from three different countries to discover the lead contamination in each product. Three top chocolate manufacturers in Europe, Japan and the U.S. were chosen to be tested in this study according to 2006 revenues (Datamonitor 2007). The method used in determining the lead traces in these chocolate samples was the atomic absorption spectrometry (AAS) as outlined by the Cocoa Producers Alliance (COPAL 2006). The objective of this study was to determine the lead levels in the chocolates produced by these manufacturers and whether these companies conform to FDA regulations.

**Methods and Materials**

*Sample collection and preparation.* The manufacturers of chocolate from Europe, Japan and the United states were chosen according to sales revenue they generated in their respective markets during the year of 2006 (Datamonitor 2007). These chocolate confectioneries include Mars Incorporated, Nestle S.A. and Hershey Company from the United States, Lindt and Sprungli from Europe, and Royce’ Confectioneries from Japan. The milk chocolate and dark chocolate
flavors of these manufacturing companies were prepared and tested. Two samples of each company’s milk and dark chocolates were prepared by using the COPAL standard preparation outlined in the Cocoa Producers Alliance protocol (2006). The samples of each prepared chocolate were digested with chosen chemical agents to remove sugars and other additives in the products.

**Procedure.** Two grams of the chocolate samples were weighed and crushed to pass through a 2 mm sieve, then placed into a 20 by 3.5 cm test tube. Ten milliliters of nitric acid (HNO₃) was added to the samples and a funnel condenser was inserted to the test tubes. The samples were then heated in a heating block at 80 to 90°C overnight followed by an additional heating of the samples again at 125 to 130°C to dryness. The samples were allowed to cool then 1 ml of HNO₃ and 4 ml of perchloric acid (HClO₄) were added. These samples were heated at 200 to 210°C to dryness with funnel condenser in place in a heating block. The samples were cooled then 4 ml of hydrochloric acid (HCl) and 50 ml of distilled water were added and then heated at 70°C for 1 hour. The tube contents were then quantitatively transferred through a retentive acid-washed filter paper receiving the filter in a 100 ml volumetric flask. The tube and filter residue were rinsed with 1% HNO₃ and made up to 100 ml volume with 1% HNO₃. Fifty milliliters of the filtered, diluted digest were transferred to a 250 ml separatory funnel
and 10 ml of citric acid was added along with 10 drops of indicator solution. If the mixture was blue, 1:5 HCl was added to just fading blue. If it was yellow, 1:3 NH₄OH was added to first detectable blue color: then 1:5 HCl was added to the fading of blue (the pH should be 3.0 to 3.2). Ten milliliters of acetyl acetone was then added and mixed with the chocolate digests. This was followed by an addition of 10 ml of chloroform (CHCl₃) and this mixture was shaken for 1 minute. The solvents were allowed to settle then the CHCl₃ layer was tapped off and discarded. Five milliliters of chelating solution and 5 ml of water-saturated methyl isobutyl ketone (MIBK) was added and mixed with shaking for about 30 seconds. After allowing the mixture to settle for one hour the aqueous layer was discarded and the MIBK layer was filtered through acid-washed filter paper.

This preparation provided the cocoa base product of the candies to be analyzed. Standards were prepared by diluting a 1000 ppm lead standard to the recommended values (0, 0.1, 0.2, 0.3, 0.4 and 0.5 ppm) for testing. The prepared standards were aspirated and tested in the AA spectrometer. This gave a standard curve to which the lead content in the chocolate samples were compared.

*Lead content analysis.* The samples of digested chocolate preparations were tested using Atomic Absorption Spectroscopy (AA). The analytic
method followed the methodology employed by the Cocoa Producers Alliance (COPAL 2006). The samples were aspirated through an acetyl flame in the AA spectrometer and lead readings were recorded. Each manufacturer’s chocolates, both dark and milk, were tested and aspirated three times. The contamination levels of the chocolate samples were reported in ppm (mg/L). The results of the chocolate samples were compared statistically by ANOVA.

**Results**

Lead contamination was evident in all chocolate samples; however, none of the samples tested exceeded the recommended limit set by the FDA (0.1 ppm). The highest value of lead was found in Mars dark chocolate 1, at 0.09 ppm. The lowest lead content was found in the Mars milk chocolate 1, which contained 0.003 ppm (Figure 1).

Figure 1: Shows the mean lead contamination of the chocolate samples, both milk and dark, from each chocolate manufacturer with standard deviation bars.
Lead contaminations among the chocolate manufacturers were compared. The European chocolate company (Lindt) showed the highest mean value of lead contamination with 0.06 ppm, whereas the Japanese confectionery (Royce) showed the least mean value of lead contamination with 0.01 ppm (Figure 2). Lead contamination was evident in all chocolate manufacturers’ samples of milk and dark chocolate. However, none of the confectioneries exceeded the FDA recommended limit of 0.1 ppm.

**Figure 2:** Comparison of mean lead contamination among the different confectioneries with standard error bars.
Milk and dark chocolate values were compared and seemed to show a difference in lead contamination. The dark chocolates that were tested showed to have a higher content of lead, whereas milk chocolate had a significantly lower level of lead contamination (Figure 3).

Figure 3: Lead contamination in Milk chocolate compared to Dark chocolate, with a P-value of 0.016 and standard deviation bars.
**Discussion**

A significant difference (p-value=0.016) was noted in the lead contamination of dark chocolate compared to its milk chocolate counterpart. This suggests that there is something in dark chocolate that was elevating the lead readings in the above tests. Milk and dark chocolate are processed the same way. The main differences between these chocolates are the ingredients added after processing and the amount of cocoa liquor used in each product. Milk chocolate ingredients that differ with dark chocolate are milk and the levels of sugar added. However, these substances were degraded during the chocolate digestion process of this experiment. Therefore, the major factor to the lead contamination has to be in the cocoa liquor. Cocoa liquor is produced by grinding, then melting the center of cocoa beans that have been dried, fermented and roasted (Manton 2006). This serves as the basis for all chocolate products, from cocoa powder to chocolate bars and candy. It is a smooth substance that can be mixed with cocoa butter to make solid chocolate bars. Dark chocolate contains a much greater portion of cocoa liquor compared to milk chocolate, which contains mostly cocoa butter. Cocoa beans generally have low lead contamination, but cocoa liquor has been reported to contain high levels of lead (Raloff 2005). Therefore, cocoa bean
processing techniques used to produce cocoa liquor should be evaluated for lead contamination.

According to the lead values in the chocolate samples from Mars Co., the FDA regulation of 0.1 ppm should be reevaluated. The value of the Mars dark chocolate, 0.09 ppm is equivalent to 0.09 mcg of lead in 1 gram of chocolate bar. The provisional tolerable weekly intake (PTWI) set by the World Health Organization (WHO) is 25 mcg/kg of body weight (Rankin et al 2005). Assuming a 33 pound (15 kg) child consumes 20g per day of this Mars dark chocolate; with absorption of 40% (ATSDR 1999); he or she would be acquiring 1.3% of the PTWI from this source alone. Chocolate can possibly increase blood lead levels among children if precautions are not taken. Therefore, Alternate protocols and methods should be used to obtain cocoa liquor if this is the source of lead contamination.

**Works Cited**


