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EVALUATION OF LEAD CONTENT OF KALE (*BRASSICA OLERACEAE*) COMMERCIALLY–AVAILABLE IN BUNCOMBE COUNTY, NORTH CAROLINA

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Abstract: Humans may be exposed to lead via leaded gasoline fumes, lead paint particles from older homes, and water contaminated by lead plumbing. In addition, the ingestion of plants that accumulate heavy metals may also lead to human exposure. Heavy metal hyperaccumulating plants such as the vegetable kale (*Brassica oleracea*) have the ability to draw heavy metals from soil. This study measured the concentration of lead in kale commercially obtained in Buncombe County, North Carolina. Three bunches of kale were selected from five different commercial sources on five separate days for a total of fifteen samples. Each sample was ashed in a muffle furnace at 800°C before being digested in 10% nitric acid and 30% hydrogen peroxide. After dissolution, samples along with a series of lead standards and reagent blanks were analyzed using a Zeeman graphite furnace atomic absorption spectrophotometer. Calibration curves were used to calculate the concentration of each sample. Only three samples had lead levels above the limit of detection (34.6 ng/g, 38.3 ng/g, and 40.0 ng/g on a dry basis). The World Health Organization has established the maximum tolerable daily intake from food, water, and air for a human to be 3.5 µg lead/kg of body mass. Therefore, an average adult (~70 kg) would need to be consume 69.9 kg of fresh kale with 40.0 ng/g lead to reach the maximum tolerable intake. Although lead intake should be avoided whenever possible, the lead concentrations in these kale samples were detectable but negligible.

Key Words: *Brassica oleraceae*; atomic absorption spectrophotometry; hyperaccumulation; lead (Pb).

INTRODUCTION

Humans have actively used lead (Pb), a naturally occurring toxic heavy metal, since at least 3500 B.C. (Phillip, 2001). An estimated 300 million tons of lead have been released into the environment since humans began using lead (Tong et al. 2000). Lead has been used in toys, fishing weights, glazes for crockery, solder for cans, kettles, and water pipes. In the United States, gasoline and house paint contained lead until banned in 1978 (EPA 2005). Although lead has been removed from paint and gasoline, lead may persist in areas where leaded fuel emissions were released and in homes with old lead paint on the walls (Phillip 2001).

Lead has a variety of negative health effects and serves no known purpose in the human body (ATSDR 1992). Health effects of lead exposures range from impaired learning abilities at low levels to coma or death at acutely high levels. People often associate lead exposure with dust from lead-based paint and occupational lead exposure. However, many other lead exposure pathways exist including through diet.

Soils may acquire lead through to contamination or it may occur naturally (Fenton 2002). Deposition of lead from combustion engine exhaust is a major source of soil contamination (Nabulo 2006). Irrigation and residential water supplies may become contaminated by flowing through lead plumbing systems or by upstream contamination. Industrial contamination, such as lead smelting, emits lead pollution into surrounding areas. After entering soil, lead persists and remains indefinitely.

"Hypertolerant plants" or "hyperaccumulators" have a greater ability to accumulate heavy metals than most other plants (Chaney et al. 1997). These plants are often used to remove heavy metals from soils in a process called "phytoremediation" (Chaney et al. 1997). Hyperaccumulating plants accumulate heavy metals in their shoots (Pollard et al. 2002). Four hundred and seventeen vascular plants have been identified as heavy metal hyperaccumulators (Pollard et al. 2002). However, only a small proportion of hyperaccumulating plants collect lead. A plant must be able to accumulate over 1000 ppm of lead to be considered a lead hyperaccumulator (Pollard et al. 2000). One quarter of known lead hyperaccumulators belong to the genus *Brassica* (Peer et al. 2003). One lead hyperaccumulator is *Brassica oleraceae,* which includes vegetables such as cabbage, broccoli, and kale. While previous studies have found elevated lead levels in cabbage, no previous reports of lead levels in commercially available kale were found (Chatterjee et al. 2005; Divrikli et al. 2003). In this study, we quantified the lead levels in commercially available kale in Buncombe County, North Carolina in the low ng/g (ppb) range.

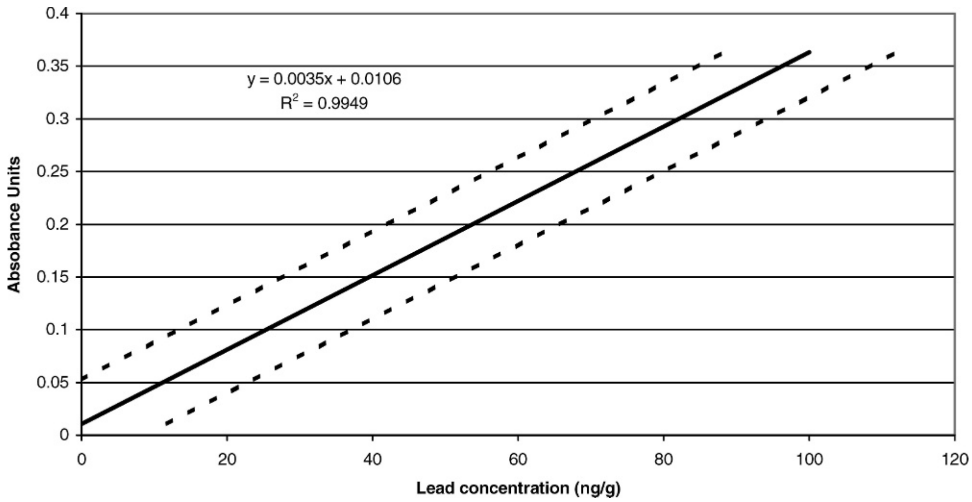

FIG. 1. Typical Calibration Curve for Lead Standards. Dashed lines are 95% confidence intervals.

METHODS

Three bunches of kale were collected from one of five commercial sources (grocery stores) on five different days, for a total of 15 bunches of kale (approx. 450 g each). Each sampling consisted of taking the top three bunches of kale from a pile as a typical customer might do. Further information on the sources of this kale was unavailable.

Portions of wet kale (approximately 100 g) were taken from each bunch and dried in a drying oven for about 12 hours at 110°C. Samples were then weighed using an analytical balance (to the nearest 0.0001 g) and transferred to acid-washed ceramic crucibles. Each sample was ashed at 800°C. After cooling, the crucible and lid of each sample were rinsed with 10% nitric acid. The rinse was transferred to a glass beaker. This step was repeated until all ashes were removed from the crucibles, using about 75 ml of acid per sample. Digestion continued with the addition of about 10 ml of 30% hydrogen peroxide. All samples were heated to about 70°C and stirred for about 0.5 hr until all ashes had dissolved. Each solution was transferred to a 100 ml volumetric flask and the remaining volume filled with distilled water and mixed. Empty crucibles with 10 ml of distilled water were also subjected to all preparation steps to create a negative control samples.

Each sample was analyzed in triplicate using a Zeeman graphite furnace atomic absorption spectrophotometer (Perkin-Elmer SIMA 6000). Lead standards with known lead concentrations ranging from 0–100 ng/g Pb were prepared by dilution of a known standard (Inorganic Ventures Lakewood, CA) and analyzed, in order to determine the concentration of lead in the unknown samples. Matrix modifiers $Mg(NO_3)_2$ (0.01 ng) and $(NH_4)_3PO_{4-}$ (0.2 ng) were added to each standard, sample, and control in order to reduce absorption interference by atoms other than lead. An instrumental batch sequence consisted of: a distilled water blank, a standard, 8 samples, a negative control sample, two additional standards and finally a distilled water blank.

RESULTS

No carryover between instrumental analyses was found. Calibration curves of absorbance versus lead concentration were reproducible and linear (Fig. 1). Using these calibration curves, sample concentrations were found and the lead levels in the original kale were calculated (Table 1). Detectable levels of lead were found in three kale samples from two commercial sources.

Results for most samples are presented as "less than" the detection limit. The slight variability in the detection limits arises due to small variations in instrument response and trace background levels found in batch blanks. The results for samples with detectable lead levels include the 95% confidence intervals for the three sub-samples with detectable lead levels (in parentheses).

DISCUSSION

Three kale samples in this study showed detectable lead levels. While no published reports were found for lead levels in commercially obtained kale (*Brassica oleraceae*), lead levels in cabbage, another member of the genus *Brassica* have been found in the range (<5 – 200.3 ug/g) (Angelova et al. 2004; Pendergrass and Butcher 2006; Chatterjee et al. 2005; Nabulo et al. 2006; Divrikli et al. 2003). The lead concentrations found in this study (ng/g) are significantly lower than to those previously reported in the literature (μg/g). The differences between the levels reported in this paper and other reports may be due to the focus of the previous research

Table 1. Average lead concentrations of kale samples (ng Pb/g dry kale). The numbers in parentheses represent the 95% confidence intervals for those samples.

Commercial Source	Sample 1	Sample 2	Sample 3
A	38.3 (27.6–48.9)	40.0 (28.0–52.0)	<30.7
B	<28.6	<35.5	<32.6
C	<28.6	<35.5	34.6 (21.3–47.9)
D	<28.2	<4.28	<31.5
E	<5.31	<4.56	<4.80

on highly contaminated soil such as sewage-sludge treated soils (Chatterjee et al. 2005) or those near roadways (Nabulo et al. 2006) and smelters (Angelova et al. 2004). Another major difference between this study and previous research is the instrumental method used. In this study, the method used is markedly more sensitive than the methods used previously. The low lead levels reported here would have been reported as <5 µg/g in previous research.

Finally, these results must be placed in a broader context. The World Health Organization set the maximum tolerable daily intake of lead from all sources (food, water, and air) at 3.5 µg lead/ kg body mass (Matloob 2003). Based on the highest possible lead concentration (40.0 ng/g) in the analyzed samples, a 70 kg person would need to consume at least 6.99 kg of dried kale per day to reach the tolerable maximum. Considering that fresh kale weighs about 10 times more than dried kale, a person would need to eat about 70 kg (154 lbs) of fresh kale per day to reach the maximum. The concentrations of lead measured in our kale samples contain negligible amounts of lead. However, full evaluation of this possible contamination pathway through soil into food requires more research particularly in areas with known soil and water contamination issues.

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