Trace Heavy Metals Analysis in Locally Bought Marquette, Michigan Produce

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Abstract

This research analyzes for trace amounts of heavy metals in locally bought organic and conventional food produce using inductively coupled plasma mass spectrometry, ICP-MS. Heavy metals are high density metals that are toxic or poisonous at low concentrations. Produce samples analyzed include apples, potatoes, lettuce, tomatoes, and onions which were selected from local stores (denoted: M, W, E, C, and S as well as from the local farmers market). Six samples of each produce type were randomly selected including three organic, and three conventional samples for each produce type from each store respectively (n=18 per produce type and organic status). These samples were then tested for ten different metals including: aluminum, arsenic, cadmium, chromium, copper, nickel, iron, lead, zinc, and magnesium. Preliminary results shown here compares heavy metal concentrations among each produce and food types for only four metals (As, Cd, Pb, and Mg) tested so far in this report. The results were then compared to the FDA safety limits for heavy metal consumption. The overall goal of this research is to profile these ten metals including iron, nickel, copper, magnesium and zinc which are considered beneficial for humans as well as for arsenic, lead, and cadmium - among other metals - which are considered harmful to human health.

Background

Heavy metal contamination in farm produce has become a major issue due to modernized farming and overuse of fertilizers. The consumption of food containing heavy metals can have negative effects on human health such as cancers, kidney dysfunction, and nervous system disorders.[1] Even in small amounts, heavy metals have long-term harmful effects due to the fact that they bioaccumulate in the body. Heavy metals can get into food in a variety of ways including through the water and soil environments, use of pesticides and fertilizers, and may then accumulate in crops grown in these environments[2].

Accumulation of heavy metals in crops, specifically the edible parts, represent a direct path for their incorporation into the human food chain[3]. Organic farming is anticipated to have lower levels of heavy metals due to the different processes used. A previous study however, found no significant differences in the amounts of trace metals in organic vs conventional[4].

Methods

- Five different types of produce were selected (apple, lettuce, onion, potato, and tomato) to assess heavy metal (Al, As, Cd, Cr, Cu, Mg, Ni, Fe, Pb, Zn) contents across five produce stores located in Marquette, MI. The stores included three local, (Marquette C, S, and E), two national, (M and W), and from the local Marquette Farmers market. A comparative study between organic and conventional was performed.
- A 500 ± 30mg sample of the produce was digested in 4 mL trace metal free nitric acid and 4 mL trace metal free water using a Multiwave GO microwave digester (Anton Paar).
- The digested samples were transferred into 15 mL centrifuge tubes, diluted to 200-fold before analysis using ICP-MS with the following parameters; Analysis type: Water MiniTorch (collision), Radio Frequency Power: 1.20 kW, Sampling depth: 5.0 Plasma Gas: 9.0 L/min, Auxiliary Gas: 1.10 L/min, Carrier Gas: 0.70 L/min, Mixed Gas: 0.0 L/min, Cell Gas: 6.0 L/min, Cell voltage: -21 v, Energy Filter: 7.0 v, low and high pump rotation speed: 20 and 60 rpm respectively.
- Samples were analyzed in DBG mode (collision cell) in order to eliminate spectral interferences
- Standard curves were constructed for each metal based on the U.S. Food & Drug Administration (FDA) maximum levels (ML). Al: 200 ppb, As: 10.0 ppb, Pb: 15.0 ppb, Cd: 5.0 ppb, Cu: 1300 ppb, Cr: 100 ppb, Fe: 300 ppb, Mg: 50,000 ppb, Ni: 100 ppb, Zn: 5000 ppb.[5]

Figure 1. The image on the left shows the process of sampling the produce; and the photo in the middle shows the produce after microwave digestion, while the image to the right is the ICP-MS instrument used for the analysis

Conclusions

The data shown is the results of analysis on four metals in all the produce type tested. Arsenic levels were mostly negligible in all food types. However, cadmium and lead levels were much higher than the FDA limits in lettuce and potato for Cd but across all produce types for Pb. Interestingly Mg, which is biologically relevant, shows mostly optimum FDA levels across all produce and food types. These results are a preliminary report on four out of the ten metals we intend to test in all the five produce and food types. Future work will increase sample number and location to include stores out side of Marquette and/or out of state to expand this research.

The findings in this academic research serves two aims:

1. Draw awareness to the Marquette community on produce quality and safety and the importance of regular testing in the produce industry and;
2. Highlight a need for increased/stricter regulatory efforts for heavy metals in the produce industry as is in case bacteria testing e.g. E.coli, due to bioaccumulation in the body which leads to long-term health effects.

Results

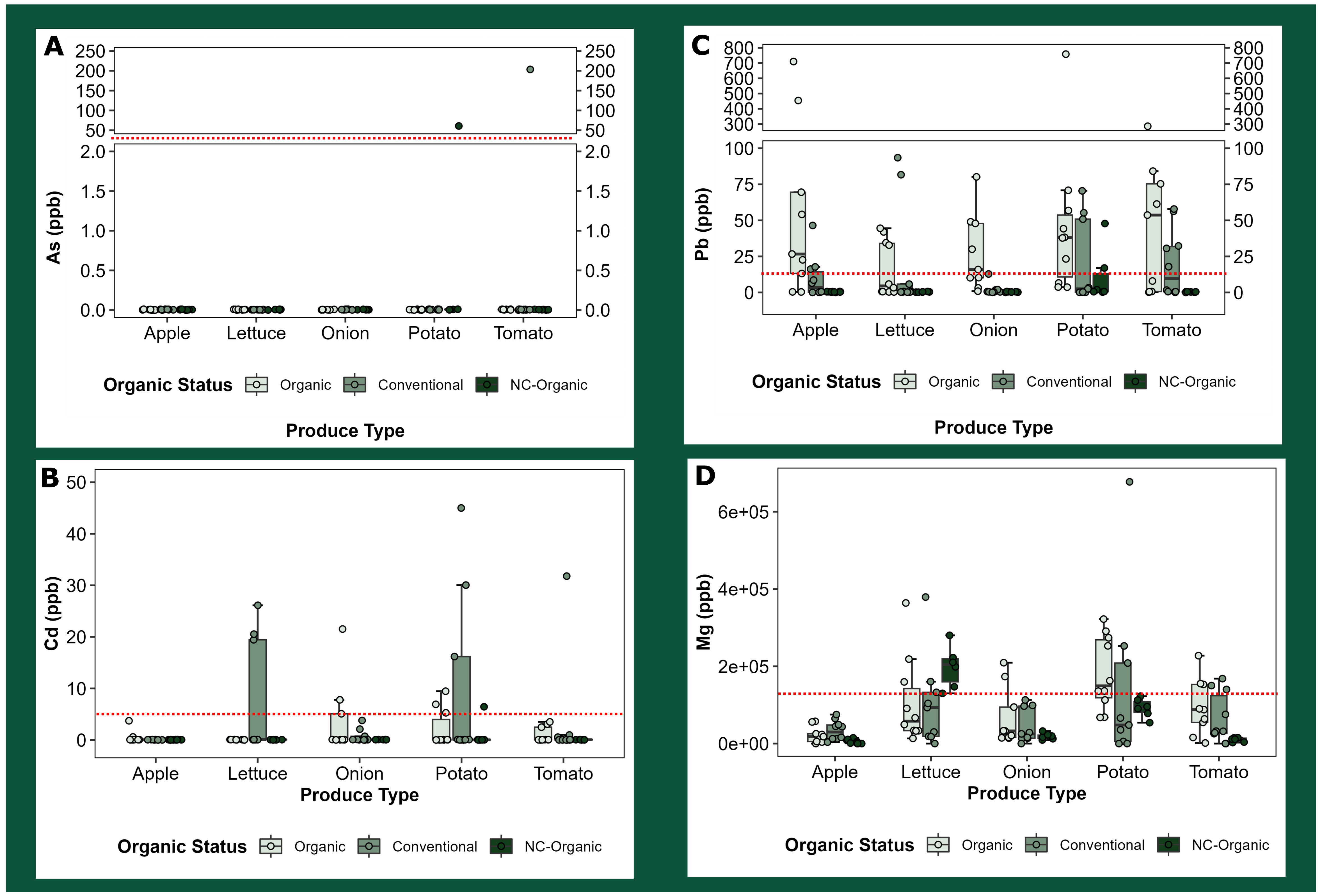

Figure 2. Plots of average heavy metal concentrations in each produce type. For multi-isotope metals, only two or three of the most abundant isotopes concentrations were determined and averaged for (A) Arsenic (As), (B) Cadmium (Cd), (C) Lead (Pb), and (D) Magnesium (Mg). Dotted red line indicates the WHO acceptable limits.

Table 1. The number of observations (n), mean ($\bar{x}$), standard error (se), and maximum value (max) summarized for all organic, conventional and not-certified organic (NC-Organic) types of produce tested for arsenic (As; ppb), cadmium (Cd; ppb), magnesium (Mg; ppb) and lead (Pb; ppb) using inductively coupled plasma mass-spectrometry (ICPMS) where results for each element are summarized as $\bar{x}$ ± se (max), respectively.

Produce Type	Organic Status	n	As (ppb) x̄ ± se (max)	Cd (ppb) x̄ ± se (max)	Mg (ppb) x̄ ± se (max)	Pb (ppb) x̄ ± se (max)
Apple	Organic	9	0.004±0.001 (0.010)	0.52±0.40 (3.72)	22520.7±7085.6 (57542.0)	150.11±84.71 (709.79)
Apple	Conventional	10	0.006±0.001 (0.010)	0.05±0.01 (0.08)	33373.4±7982.4 (75086.4)	9.67±4.61 (46.46)
Apple	NC-Organic	12	0.005±0.001 (0.009)	0.04±0.01 (0.09)	4238.2±1406.7 (14880.0)	0.42±0.05 (0.67)
Lettuce	Organic	10	0.005±0.001 (0.009)	0.05±0.01 (0.08)	106238.3±35189.7 (363858.7)	16.49±6.09 (44.53)
Lettuce	Conventional	9	0.004±0.000 (0.006)	7.38±3.71 (26.13)	103967.6±39232.8 (379169.3)	20.39±12.75 (93.46)
Lettuce	NC-Organic	6	0.005±0.001 (0.009)	0.05±0.01 (0.08)	198053.7±22152.5 (280111.1)	0.35±0.07 (0.66)
Onion	Organic	9	0.004±0.001 (0.007)	3.85±2.40 (21.52)	67669.1±24962.8 (209314.2)	27.49±8.89 (80.15)
Onion	Conventional	9	0.006±0.001 (0.010)	0.76±0.44 (3.78)	45016.3±14787.9 (112842.0)	2.10±1.35 (12.81)
Onion	NC-Organic	6	0.005±0.001 (0.008)	0.07±0.01 (0.09)	18816.7±3337.0 (32364.4)	0.36±0.09 (0.66)
Potato	Organic	10	0.005±0.001 (0.009)	2.19±1.14 (9.46)	182285.4±29875.9 (322169.8)	104.37±73.03 (758.44)
Potato	Conventional	9	0.006±0.001 (0.010)	10.16±5.60 (45.00)	143741.5±73411.3 (677280.9)	20.34±9.79 (70.46)
Potato	NC-Organic	6	10.138±10.132 (60.800)	1.10±1.07 (6.44)	92250.0±10021.7 (122711.1)	11.33±7.76 (47.79)
Tomato	Organic	9	0.006±0.001 (0.010)	1.03±0.50 (3.50)	94376.8±24219.6 (227525.3)	63.28±30.07 (285.79)
Tomato	Conventional	10	20.344±20.340 (203.400)	3.35±3.16 (31.78)	65145.4±20315.5 (168058.7)	19.79±7.38 (57.86)
Tomato	NC-Organic	6	0.004±0.001 (0.008)	0.04±0.01 (0.08)	9881.4±2209.4 (15226.7)	0.33±0.08 (0.53)

References

[1] Latif A, Bilal M, Asghar W, Azeem M, Ahmad MI, et al. (2018) Heavy Metal Accumulation in Vegetables and Assessment of their Potential Health Risk. J Environ Anal Chem 5: 234. doi:10.4172/2380-2391.1000234
[2] Kohrman H, Chamberlain CP. Heavy metals in produce from urban farms in the San Francisco Bay Area. Food Addit Contam Part B Surveill. 2014;7(2):127-34. doi: 10.1080/19393210.2013.859740. Epub 2014 Jan 8. PMID: 24914598.
[3] Singh, S.; Zacharias, M.; Kalpana, S.; Mishra, S. Heavy metals accumulation and distribution pattern in different vegetable crops. J. Environ. Chem. Ecotoxicol. 2012,4, 170–177.
[4] Jorhem, L., & Slanina, P. (2000). Does organic farming reduce the content of Cd and certain other trace metals in plant foods? A pilot study. *Journal of the Science of Food and Agriculture*, *80*(1), 43-48.
[5] United Stated Government. U.S. Food and Drug Administration. Retrieved April 26, 2022 from https://www.accessdata.fda.gov

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