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Study Review

Mineral nutrient composition of vegetables, fruits and grains: The context of reports of apparent historical declines

Robin J. Marles

Senior Scientific Advisor, Nutrition Premarket Assessment Division, Bureau of Nutritional Sciences, Food Directorate, Health Canada, 251 Sir Frederick Banting Driveway (Mail Stop 2203E), Ottawa, Ontario K1A 0K9, Canada

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ABSTRACT

Reports of apparent historical declines in mineral nutrients of vegetables, fruits and grains, allegedly due to soil mineral depletion by agriculture, triggered this critical review. Comparisons of food composition data published decades apart are not reliable. Over time changes in data sources, crop varieties, geographic origin, ripeness, sample size, sampling methods, laboratory analysis and statistical treatment affect reported nutrient levels. Comparisons with matching archived soil samples show soil mineral content has not declined in locations cultivated intensively with various fertilizer treatments. Contemporaneous analyses of modern versus old crop varieties grown side-by-side, and archived samples, show lower mineral concentrations in varieties bred for higher yields where increased carbohydrate is not accompanied by proportional increases in minerals – a "dilution effect". Apparent declines, e.g., the extreme case of copper from −34% to −81%, represent small absolute changes: per 100 g dry weight vegetables have 0.11–1.71 mg (1555% natural range of variation), fruit 01–2.06 mg (20,600% range), and grains 0.1–1.4 mg (1400% range); copper composition is strongly subject to the dilution effect. The benefits of increased yield to supply food for expanding populations outweigh small nutrient dilution effects addressed by eating the recommended daily servings of vegetables, fruits and whole grains.

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1. Introduction

Internet articles and popular press frequently state that the mineral nutrient composition of vegetables, fruits and grains has been declining over the past 50 years. These sources may cite, as supporting evidence, scientific literature that compared nutrient data from food composition tables published many years apart, even though the authors of the scientific literature cited often explicitly recognized limitations of their data and analysis. Apparent historical declines in food mineral nutrient content derived from food composition table comparisons have been attributed by popular press authors to a decrease in the levels of micronutrients in the soil due to depletion by intensive agriculture, even when that was not a cause identified in the scientific articles they cite.

E-mail address: robin.marles@hc-sc.gc.ca (R.J. Marles).

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The objectives of this article are to review and analyze the available scientific evidence for changes in the mineral nutrient composition of vegetables, fruits and grains, and their possible causes, and to assess the significance of validated analytical findings with regard to the nutritional well-being of consumers.

2. Background: public perception based on the popular press

In the popular press and on the internet, a very frequently repeated quotation is, "A Kushi Institute analysis of nutrient data from 1975 to 1997 found that average calcium levels in 12 fresh vegetables dropped 27%; iron levels 37%." The Kushi Institute (http://www.kushiinstitute.org/) is an organization that describes itself as having a "macrobiotic approach to health and healing" that promotes healing foods and lifestyle changes for health improvement. The numbers come from an article written by Jack (1998), a health writer associated with the Kushi Institute, comparing U.S. Department of Agriculture (USDA) food composition tables from 1997 versus 1975, to identify changes in the levels of nutrients in fresh foods. The quotation comes from an open letter to the U.S. Secretary of Agriculture, Dan Glickman, written by *Organic Gardening* Senior Editor Cheryl Long (Long, 1999). Thus, while the original source of information, USDA food composition tables, is authoritative, a direct comparison of the values does not take into consideration differences in crop varieties or methods of nutrient analysis, and provides no information on potential causes of reported differences. The Kushi Institute report was apparently not subjected to scientific peer-review.

Thomas (2000) prepared a report on historical nutrient content changes that was published by Mineral Resources International (UK) Ltd., an ingredient supplier and manufacturer of liquid and tablet nutritional supplements using minerals and trace minerals from Utah's Great Salt Lake. Thomas compared data on 27 varieties of vegetables, 17 varieties of fruit, 10 cuts of meat and some milk and cheese products, using nutrient composition tables from the U.K.'s *McCance and Widdowson's The Composition of Foods* first edition published in 1940 compared with the data for the same foods from the fifth edition published in 1991. He concluded that the results demonstrated that there has been a significant loss of mineral macronutrients and trace elements in these foods over that period of time, with the most dramatic losses relating to the copper (Cu) present in vegetables between 1940 and 1991 (76%) and zinc (Zn) between 1978 and 1991 (59%). He suggested that the results of the study can be linked to recent dietary, environmental and disease trends, including contamination of vegetables, fruits and meat with pesticides, hormones, heavy metals, antibiotics and food additives, trace mineral depletion of the soil, excessive use of nitrogen-phosphorus-potassium (N-P-K) fertilizers, changes in crop varieties, loss of micro flora/fauna within the soil, etc. However, he provided no supporting evidence for these factors as explanations for the differences he observed.

Another widely cited report is an *Earth Talk* column written and edited by Scheer and Moss (2011) for *E – The Environmental Magazine*, which is published on the *Scientific American* website. This is often cited as an article published in the journal *Scientific American*, which is not correct. The column, written as a response to a reader's question about nutritional differences in a carrot eaten today from one eaten in 1970, states categorically that fruits and vegetables grown decades ago were much richer in vitamins and minerals than the varieties available today and that "the main culprit in this disturbing trend is soil depletion: Modern intensive agricultural methods have stripped increasing amounts of nutrients from the soil in which the food we eat grows. Sadly, each successive generation of fast-growing, pest-resistant carrot is truly less good for you than the one before." They cite as supporting evidence the Kushi Institute study and two scientific studies (Davis et al., 2004; Mayer, 1997; both discussed in detail below) despite the fact that none of these studies present any evidence that a change in soil mineral nutrient content is an important causative factor.

3. Scientific evidence from food composition table comparisons

One of the first and most frequently cited peer-reviewed scientific papers on apparent historical changes in the mineral content of fruits and vegetables was published by Mayer in 1997. She compared the results of analyses for 8 mineral nutrients: sodium (Na), K, calcium (Ca), magnesium (Mg), P, iron (Fe), Cu, and Zn, in 20 fruits and 20 vegetables, raw, peeled, from two U.K. *Chemical Composition of Foods* reports dating from 1960 (reporting results from analyses done in 1936) and 1991. The foods were not dried or rehydrated and dry pulses were excluded. She reported finding statistically significant reductions in the levels of Ca (−19%, $P = 0.014$), Mg (−35%, $P < 0.001$), Cu (−81%, $P < 0.001$), and Na (−43%, $P = 0.013$) in vegetables and Mg (−11%, $P = 0.016$), Fe (−32%, $P = 0.002$), Cu (−36%, $P = 0.006$) and K (−20%, $P < 0.001$) in fruits. The only mineral nutrient that showed no significant difference over the ~50 year period was P. Mayer noted that potential sources of deviation included possible differences in the methods of sampling; methods of analysis (although older methods were characterized as taking longer but no less accurate); mixed sources of data for the 1991 edition; greater use of imported and "out of season" produce; different storage and ripening systems; and changes in varieties bred for higher yield, response to modern methods of agriculture, post-harvest handling qualities and cosmetic appeal. She noted that water content increased significantly and dry matter content decreased significantly in fruits between the new and old data sets but did not attempt to correct for moisture content. Mayer stated that "in principle, modern agriculture could be reducing the mineral content of fruits and vegetables" but noted that evidence was needed to find out if this was significant. She did not demonstrate a cause-and-effect relationship between her findings and soil mineral content, nor did she present evidence that any of the nutrient content changes were of importance to human nutrition. She identified these as areas for future research.

Lyne and Barak (2000) reviewed the evidence for depleted soils causing a reduction in the mineral content of food crops as suggested by comparison of USDA food composition data. They found that for three major cations: Ca^{2+}, Mg^{2+}, and K^{+} of selected fresh produce crops, there was no real loss in the balance of mineral nutrition in food crops. They stated that widespread use of soil testing and fertilizers as part of the strategy for the increasing yields of modern agriculture argues strongly against the notion of widespread soil depletion of mineral nutrients. They concluded that although it may be hypothesized that a decline in soil quality has led to an apparent decline in food nutrition, more controlled studies are needed to factor out the many variables associated with the food composition tables and this type of analysis.

Bringing more statistical rigour to the food composition table comparison approach, Davis et al. (2004) compared USDA Food Composition Table data from 1950 and 1999, for water, energy, protein, fat, carbohydrate, ash, Ca, P, Fe, vitamin A, thiamin, riboflavin, niacin, and ascorbic acid in 39 vegetables, 3 melons and strawberries. Fibre was excluded due to the change of analysis from "crude" to "dietary" fibre. Dry matter content was calculated by difference with the water content, and 1950 nutrient content values were adjusted to the same moisture level as the 1999 data by multiplying them by the ratio of dry matter in 1999 samples over dry matter in 1950 samples.

Davis et al. (2004) found that changes for individual foods could not be assessed reliably due to large uncertainties in the mineral