Declining Fruit and Vegetable Nutrient Composition: What Is the Evidence?

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***Abstract*. Three kinds of evidence point toward declines of some nutrients in fruits and vegetables available in the United States and the United Kingdom: 1) early studies of fertilization found inverse relationships between crop yield and mineral concentrations—the widely cited "dilution effect"; 2) three recent studies of historical food composition data found apparent median declines of 5% to 40% or more in some minerals in groups of vegetables and perhaps fruits; one study also evaluated vitamins and protein with similar results; and 3) recent side-by-side plantings of low- and high-yield cultivars of broccoli and grains found consistently negative correlations between yield and concentrations of minerals and protein, a newly recognized genetic dilution effect. Studies of historical food composition data are inherently limited, but the other methods can focus on single crops of any kind, can include any nutrient of interest, and can be carefully controlled. They can also test proposed methods to minimize or overcome the diluting effects of yield whether by environmental means or by plant breeding.**

This article summarizes three kinds of evidence pointing toward declines during the last 50 to 100 years in the concentration of some nutrients in vegetables and perhaps also in fruits available in the United States and the United Kingdom.

INVERSE RELATIONS BETWEEN PLANT YIELD AND MINERAL CONCENTRATION

This article summarizes three kinds of evidence pointing toward declines during the last 50 to 100 years in the concentration of some nutrients in vegetables and perhaps also in fruits available in the United States and the United Kingdom. It has been noted since the 1940s that yield increases produced by fertilization, irrigation, and other environmental means tend to decrease the concentrations of minerals in plants. Jarrell and Beverly (1981) reviewed the evidence for this well-known "dilution effect." Although their review has been cited over 180 times (60 times from 2000 on), few mentions of the dilution effect contain a reference, suggesting that the effect is widely regarded as common knowledge. Citations to the review are diverse, involving (in descending order), grains, fruits and vegetables, trees and shrubs, legumes, pasture plants, and flowers. The most commonly cited fruits and vegetables are tomatoes, potatoes, taro, onions, peppers, and berries.

Jarrell and Beverly cited the example of red raspberry plants grown in soil with 12 ppm of phosphorus (P) and fertilized with additional amounts of 0, 22, and 44 ppm P (Hughes et al., 1979). After 8 months, plants grown with 44 ppm of added P had ≈20% higher concentration of P than unfertilized plants (dry weight basis). However, the concentrations of all eight other measured minerals declined, usually by 20% to 55% (Fig. 1). Fertilization produced large increases in plant dry matter, 37% at 22 ppm and 119% at 44 ppm. Thus, the fertilized plants contained larger absolute amounts of minerals than the unfertilized plants, but these amounts were sufficiently diluted by the increased dry matter that all mineral concentrations declined, except for P.

APPARENT NUTRIENT DECLINES IN HISTORICAL FOOD COMPOSITION DATA

There are three quantitative reports of apparent median or average declines of nutrients in groups of vegetables or fruits (Davis et al., 2004; Mayer, 1997; White and Broadley, 2005). The groups of foods usually numbered from 20 to 45. All authors calculated ratios of nutrient contents, R = new/old, for each food and nutrient, where the new and old dates differed by ≈50 to 70 years. To assess possible declines in the groups as a whole, Mayer and White and Broadley calculated geometric means of R for each nutrient and used *t* tests of the hypotheses that the group geometric means equaled 1. (Geometric means derive from means of log R values.) Davis et al. (2004) and Davis (2006) noted that the distributions of log R usually deviate significantly or strongly from the normality assumption of *t* tests and associated confidence intervals (CIs). They preferred the alternate statistical method of testing the hypotheses that the group medians of R equaled 1. For this purpose, they used sign (quantile) tests and CIs that make no assumption about the distributions of R. They also compared results of the two statistical methods. Mayer calculated R values based on nutrient concentrations per fresh weight, whereas the others calculated R values on an equal moisture/dry weight basis. Nutrient content data came from U.K. foods (Mayer and White and Broadley) and U.S. foods (Davis et al. and White and Broadley). In some cases, White and Broadley evidently used the same U.K. data as Mayer; ≈40% of White and Broadley's R values for U.K. vegetables and fruits are the same as Mayer's (± 5% after adjustment to dry weight basis).

Figures 2 through 6 show the major results, after recalculation by me to a consistent, conservative analysis: median R values on a dry weight basis with distribution-independent 95% CIs and statistical significance by two-tailed sign tests (Davis, 2006; Davis et al., 2004). For comparison, the figures also show geometric mean R values and two-tailed statistical significance as originally reported, on a fresh weight basis in the case of Mayer's data (Fig. 2).

These Figures 2 through 6 point strongly toward apparent median nutrient declines (median R < 1). Excluding Mayer's results, which partially duplicate White and Broadley's U.K. findings, and excluding the energy source, carbohydrate (Fig. 3), there are 33 nutrient comparisons in Figures 3 through 6. Among the 33 median R values, 25 (76%) are less than 1 (declines), and 11 (33%) are sufficiently so to be statistically significant ($P < 0.05$). In contrast, among the eight medians that slightly exceed 1, none are statistically significant. The strongest evidence for declines occurs for minerals in vegetables, especially calcium and copper (Cu), with median declines ≈17% and 80%. This 80% decline for Cu is perhaps questionably large, but Cu also showed the largest dilution effect among the eight minerals reported in red raspberry plants (Fig. 1). For fruits, my recalculated median R values show only relatively small and uncertain declines in minerals (Figs. 2 and 5).

The one study that considered protein and vitamins found apparent median declines in 43 garden crops (nearly all vegetables) amounting to 6% for protein and 15% to 38% for three of the five vitamins studied (Fig. 3).

For P, U.S. data point toward declines with median R = 0.91 in Figure 3 ($P = 0.002$)

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