Historical changes in the mineral content of fruits and vegetables

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Implies that a balance of the different essential nutrients is necessary for maintaining health. The eight minerals that are usually analysed are Na, K, Ca, Mg, P, Fe, Cu, Zn. A comparison of the mineral content of 20 fruits and 20 vegetables grown in the 1930s and the 1980s (published in the UK Government's *Composition of Foods* tables) shows several marked reductions in mineral content. Shows that there are statistically significant reductions in the levels of Ca, Mg, Cu and Na in vegetables and Mg, Fe, Cu and K in fruit. The only mineral that showed no significant differences over the 50 year period was P. The water content increased significantly and dry matter decreased significantly in fruit. Indicates that a nutritional problem associated with the quality of food has developed over those 50 years. The changes could have been caused by anomalies of measurement or sampling, changes in the food system, changes in the varieties grown or changes in agricultural practice. In conclusion recommends that the causes of the differences in mineral content and their effect on human health be investigated.

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The purpose of this paper is to address the question: has the nutritional quality (particularly essential mineral content) of fruits and vegetables changed this century during the period of changes in the food system and modernization in agriculture? The UK Government's *Composition of Foods* data provides a source of data at two time points separated by approximately 50 years; by comparing this data I attempt to answer this question.

The composition of foods tables

The first edition of the UK *Chemical Composition of Foods*[1] arose from a need to provide investigators with information for a wide range of foods consumed in the UK. The data on fruit and vegetables were compiled from previous studies of the composition of foods[2]. Unfortunately, these reports were destroyed in a fire during the Second World War and have been out of print ever since. This means that exact dates or details of the analyses are not known.

Since the first edition there have been four subsequent updates of the full *Composition of Foods* tables. It wasn't until the fifth edition, however, that the tables included substantial revisions of the original data on fruits and vegetables that were listed in the first edition.

The fifth edition of *The Composition of Foods*[3] addressed a need for updates of the old data. The introductory section states "The nutritional value of many of the more traditional foods has changed. This can happen when there are new varieties or new sources of supply for raw materials; with new farming practices which can affect the nutritional value of both plant and animal products…"

The updated compositions of fruits and vegetables are based on analytical studies commissioned by the Ministry of Agriculture, Fisheries and Food (MAFF). The samples were designed to reflect the usual pattern of consumption in the UK at the time of analysis. The tables are not designed to provide comparative historical data – the fruit and vegetables would not necessarily have been grown in similar conditions, soils, or times of year or be of the same varieties. The data were also provided by mixed sources (see below). More controlled data would have been better, but this data nevertheless provides a good starting point for the comparison.

The updated vegetable analyses were carried out by the Institute for Food Research between 1984 and 1987 and have been used for all the vegetable mineral data. The updated fruit analyses were based largely on data from the Laboratory of the Government Chemist (LGC). Most of the twenty fruits listed, however, include data from other sources for one or more of the minerals. For instance, the entry for cooking apples makes use of data from the LGC for P, Fe, Cu and Zn. The values for Na, K, Ca, Mg are an average of LGC data and the old *Chemical Composition of foods* data from 1936. Table I lists sources of data for all the twenty vegetables and fruits that were selected for the comparison.

In this paper I have examined only raw fruits and vegetables. This has been done to exclude differences caused by changes in methods of processing. The updated analyses provide an opportunity to compare the changes in purchased raw food over approximately a 50-year period.

Methods

I analysed twenty vegetables and fruits using two versions of the *Composition of Foods* tables[3,4]. I used the 1960 version for the old data because it was easily available and includes the same analyses as the first and second editions. It also reports the results to one more significant digit than the fourth edition. The fruits and vegetables selected had to meet the following criteria:

- The old data had been updated for the fifth edition of the food tables. Some fruits have also been included when old and new data were averaged as outlined in Table I.
- The descriptions of the analysed portion of the food were identical. For example, both samples were peeled.
- Only raw samples were included.
- The food was not dried or rehydrated and dry pulses were not included.
- The food was not a condiment (e.g. horseradish root).

Table I
Sources of data for *The Composition of Foods* tables

Fruits	Sources and dates of data
Apricots	LGC 85-86 except Na: average of literature
Bananas	LGC 85-86 except K, Zn: average of literature
Blackberries	LGC 85-86
Cherries	LGC 85-86
Cooking apples	LGC 85-86 except Na, K, Ca, Mg: average of LGC, MW4
Eating apples	LGC 85-86 except Na, K, Cu: average of literature
Grapefruit	LGC 85-86 except Na, K, Ca: average MW4, USDA 86, literature
Grapes	LGC 85-86 except Na, K, Zn: average of literature
Lemons	MW4, USDA, literature.
Melon cantaloupe	LGC 85-86
Nectarines	LGC 85-86 except K, Mg: literature
Oranges	LGC 85-86 except K: literature
Passion fruit	Literature sources
Peaches	LGC 85-86 except K: literature
Pears	LGC 90
Pineapple	LGC 85-86, MW4, literature
Plums	Recalculated from stewed plums
Raspberries	LGC 85-86
Rhubarb	Average of USDA 81, MW4
Strawberries	LGC 85-86

Notes:
LGC Laboratory of the Government Chemist
MW4 *McCance and Widdowson's Composition of Foods* 4th edition (1936 data)[6]
USDA United States Department of Agriculture data
First to third editions: The data used in the first four editions of the *Chemical Composition of Foods* were compiled from the 1936 data[2]
Fourth edition: The data were compiled from the 1936 data with a few additions from the literature. For example Zn values were added from literature sources
Fifth edition: The data for vegetables in the fifth edition were all taken from the Institute of Food Research between 1984 and 1987. The data for fruits were obtained from mixed sources

A total of 20 fruits and 20 vegetables satisfied these criteria and these are listed with their mineral contents at both time points in Table III.

I calculated the logarithm of the ratios (new:old) for each mineral for each fruit and vegetable and from these computed the geometric means. Students *t*-test was used to test whether each mean ratio was significantly different from 1. The logs of the ratios were used for this test.

Findings

The average ratios and results of the *t*-test are listed in Table II. A ratio of 0.81 for

Table II
Average[a] ratio of mineral content (new:old) of 20 vegetables and 20 fruits[b]

	Ca	Mg	Fe	Cu	Na	K	P	Dry matter	H_2O
Vegetables ratio	0.81	0.65	0.78	0.19	0.57	0.86	0.94	0.97	1.00
***p* value**[c]	0.014*	0.000*	0.088	0.000**	0.013*	0.090	0.487	0.53	0.872
Fruits ratio	1.00	0.89	0.68	0.64	0.90	0.80	0.99	0.91	1.02
***p* value**	0.957	0.016*	0.002**	0.006**	0.561	0.000**	0.903	0.023*	0.006**

Notes: [a] Geometric mean, the antilogarithm of the mean of the logarithm of the ratio of 1980s to 1930s values
[b] See text for data sources and Table III for vegetables and fruits included. Analyses of Mn, Se and I were only added in the 1991 edition. Zn was only added in the 1978 edition. S was omitted from the 1991 tables although it was analysed in previous editions. C1 was not revised in many cases for the 1991 edition. For these reasons comparisons were only possible for the above 7 minerals, water and dry matter.
[c] Probability that average of logarithm of new:old is statistically different from 0 by *t*-test. (This is equivalent to the ratios being different from 1)
* = significant at the 5 per cent level
** = significant at the 2 per cent level

calcium, for example, means that over an approximate 50-year period the average content of calcium in vegetables has declined to 81 per cent of the original level.

There were significant reductions in the levels of Ca, Mg, Cu and Na, in vegetables and Mg, Fe, Cu and K in fruits. The greatest change was the reduction of copper levels in vegetables to less than one-fifth of the old level. The only mineral that showed no significant differences over the 50-year period was P. Water increased significantly

Table III
Mineral content of vegetables and fruit (mg/100mg)

	Ca old	Ca new	Mg old	Mg new	Fe old	Fe new	Cu old	Cu new	Na old	Na new	K old	K new	P old	P new	Dry Matter old	Dry Matter new	H_2O% old	H_2O% new
Vegetables																		
Beetroot	24.9	20.0	15.0	11.0	0.37	1.0	0.07	0.02	84.0	66.0	303.0	380.0	32.1	51	12.9	12.9	87.1	87.1
Brussels Sprouts	28.7	26.0	19.6	8.0	0.66	0.7	0.05	0.02	9.6	6.0	515.0	450.0	78.4	77.0	15.7	15.7	84.3	84.3
Cabbage – winter	72.3	68.0	16.8	6.0	1.23	0.6	N	0.02	28.4	3.0	240.0	270.0	64.1	46.0	9.4	10.3	90.6	89.7
Carrots – old	48.0	25.0	12.0	3.0	0.56	0.3	0.08	0.02	95.0	25.0	224.0	170.0	21.0	15.0	10.2	10.2	89.8	89.8
Celery	52.2	41.0	9.60	5.0	0.61	0.4	0.11	0.01	137.0	60.0	278.0	320.0	31.7	21.0	6.5	4.9	93.5	95.1
Lettuce	25.9	28.0	9.7	6.0	0.73	0.70	0.15	0.01	3.1	3.0	208	220	30.2	28.0	4.8	4.9	95.2	95.1
Mushroom	2.9	6.0	13.2	9.0	1.03	0.6	0.64	0.72	9.1	5.0	467.0	320.0	136.0	80.0	8.5	7.4	91.5	92.6
Mustard and cress	65.9	50.0	27.3	22.0	4.54	1.0	0.12	0.01	19.0	19.0	337.0	110.0	65.5	33.0	7.5	4.7	92.5	95.3
Onions	31.2	25.0	7.6	4.0	0.30	0.30	0.08	0.05	10.2	3.0	137.0	160.0	30.0	30.0	7.2	11.0	92.8	89.0
Parsley	325.0	200.0	52.2	23.0	8.00	7.7	0.52	0.03	33.0	33.0	1,080.0	760.0	128.0	64.0	21.3	16.9	78.7	83.1
Parsnips	54.8	41.0	22.4	23.0	0.57	0.6	0.10	0.05	16.5	10.0	342.0	450.0	69.0	74.0	17.5	20.7	82.5	79.3
Peas	15.1	21.0	30.2	34.0	1.88	2.8	0.23	0.05	0.5	1.0	342.0	330.0	104.0	130.0	21.5	25.4	78.5	74.6
Potatoes – old	7.7	5.0	24.2	17.0	0.75	0.4	0.15	0.08	6.5	7.0	568.0	360.0	40.3	37.0	24.2	21.0	75.8	79.0
Pumpkin	39.0	29.0	8.2	10.0	0.39	0.4	0.08	0.02	1.3	0.0	309.0	130.0	19.4	19.0	5.3	5.0	94.7	95.0
Runner beans	33.3	33.0	23.0	19.0	0.74	1.2	0.09	0.02	6.5	0.0	276.0	220.0	25.9	34.0	8.4	8.8	91.6	91.2
Radishes	43.7	19.0	11.4	5.0	1.88	0.6	0.13	0.01	59.0	11.0	240.0	240.0	27.1	20.0	6.7	4.6	93.3	95.4
Swedes	56.4	53.0	10.8	9.0	0.35	0.1	0.05	0.01	52.2	15.0	136.0	170.0	19.0	40.0	8.6	8.8	91.4	91.2
Tomatoes	13.3	7.0	11.0	7.0	0.43	0.5	0.10	0.01	2.8	9.0	288.0	250.0	21.3	24.0	6.6	6.9	93.4	93.1
Turnips	58.8	48.0	7.4	8.0	0.37	0.2	0.07	0.01	58.0	15.0	238.0	280.0	27.5	41.0	6.7	8.8	93.3	91.2
Watercress	222.0	170.0	17.0	15.0	1.62	2.2	0.14	0.01	60.0	49.0	314.0	230.0	52.0	52.0	8.9	7.5	91.1	92.5
Fruits																		
Apricots	17.2	15.0	12.3	11.0	0.37	0.5	0.12	0.06	N	2.0	320.0	270.0	21.3	20.0	13.4	12.8	86.6	87.2
Bananas	6.8	6.0	41.9	34.0	0.41	0.3	0.16	0.10	1.2	1.0	348.0	400.0	28.1	28.0	29.3	24.9	70.7	75.1
Blackberries	63.3	41.0	29.5	23.0	0.85	0.7	0.12	0.11	3.7	2.0	208.0	160.0	23.8	31.0	18.0	15.0	82.0	85.0
Cherries	15.9	13.0	9.6	10.0	0.38	0.2	0.07	0.07	2.8	1.0	275	210	16.8	21.0	18.5	17.2	81.5	82.8
Cooking apples	3.6	4.0	2.9	3.0	0.29	0.1	0.09	0.02	21.0	2.0	123.0	88.0	16.2	7.0	14.4	12.3	85.6	87.7
Eating apples	3.6	3.0	4.7	3.0	0.29	0.1	0.11	0.02	2.4	3.0	118.0	100.0	7.7	8.0	15.7	14.6	84.3	85.4
Grapes	11.7	13.0	5.3	7.0	0.34	0.3	0.09	0.12	1.7	2.0	283.0	210.0	19.0	18.0	20.0	18.2	80.0	81.8
Grapefruit	17.1	23.0	10.4	9.0	0.26	0.1	0.06	0.02	1.4	3.0	234.0	200.0	15.6	20.0	9.3	11.0	90.7	89.0
Lemons	107.0	85.0	11.6	12.0	0.35	0.5	0.26	0.26	6.0	5.0	163.0	150.0	20.7	18.0	14.8	13.7	85.2	86.3
Melon cantaloupe	19.1	20.0	20.1	11.0	0.81	0.3	0.04	0.00	13.5	8.0	319.0	210.0	30.4	13.0	6.4	7.9	93.6	92.1
Nectarines	3.9	7.0	12.6	10.0	0.46	0.4	0.06	0.06	9.1	1.0	268.0	170.0	23.9	22.0	19.8	11.1	80.2	88.9
Oranges	41.3	47.0	12.9	10.0	0.33	0.1	0.07	0.05	2.9	5.0	197	150	23.7	21.0	13.9	13.9	86.1	86.1
Passion fruit	15.6	11.0	38.6	29.0	1.12	1.3	0.12	N	28.4	19.0	348.0	200.0	54.2	64.0	26.7	25.1	73.3	74.9
Peaches	4.8	7.0	7.9	9.0	0.38	0.4	0.05	0.06	2.7	1.0	259.0	160.0	18.5	22.0	13.8	11.1	86.2	88.9
Pears	7.5	11.0	7.2	7.0	0.21	0.2	0.15	0.06	2.3	3.0	128.0	150.0	9.7	13.0	16.8	16.2	83.2	83.8
Pineapple	12.2	18.0	16.9	16.0	0.42	0.2	0.08	0.11	1.6	2.0	247.0	160.0	7.8	10.0	15.7	13.5	84.3	86.5
Plums	12.4	13.0	7.6	8.0	0.33	0.4	0.10	0.10	1.9	2.0	192.0	240.0	15.4	23.0	15.4	16.1	84.6	83.9
Raspberries	40.7	25.0	21.6	19.0	1.21	0.7	0.21	0.10	2.5	3.0	224.0	170.0	28.7	31.0	16.8	13.0	83.2	87.0
Rhubarb	103.0	93.0	13.6	13.0	0.40	0.3	0.13	0.07	2.2	3.0	425.0	290.0	21.0	17.0	5.8	5.8	94.2	94.2
Strawberries	22.0	16.0	11.7	10.0	0.71	0.4	0.13	0.07	1.5	6.0	161.0	160.0	23.0	24.0	11.1	10.5	88.9	89.5

Notes: Old: *Composition of Foods* 3rd edition (1930s data)[4]
New: *Composition of Foods* 5th edition (1980s data)[3]
N: No data available
Ca, Mg, Fe, Na, K and P were reported to one fewer significant digits in the 1991 tables.

and dry matter decreased significantly in fruits.

What role do the minerals play in human nutrition?

Minerals all have several roles in human biochemistry and physiology and all the minerals mentioned above are essential in the diet of humans. Many are co-factors for different enzymes and we are dependent on them for energy efficiency, fertility, mental stability and immunity. Although fruits and vegetables generally supply a small proportion of total mineral dietary requirements, the reductions could be important to some groups so the causes of the reductions need investigating. It is not clear what is causing the reductions. There are several possibilities and these are outlined below.

Are the reductions anomalies of measurement or sampling?

The earlier analyses of some minerals may have been inaccurate compared to modern analytical methods. Elsie Widdowson, however, notes in the introduction to *The Composition of Foods*[3] that "those methods were no less accurate than the modern automated ones, but they took a much longer time". If this is true, we should be able to rely on the consistency of the analytical methods. However, there has been much debate over this question and no clear conclusion has been reached.

The methods of sampling fruit and vegetables were designed to reflect the usual choice of foods at the time of the research. There could be differences in the methods of sampling. It is not possible to compare the details of the methods used because the original data are no longer available. Also, the use of mixed sources of data for the 1991 edition of *The Composition of Foods*[3] is an unknown factor and possible source of bias. It is not known whether the first edition of the *Chemical Composition of Foods*[1] used similar methods of data compilation.

Food system changes

In the past sixty years the food supply system has changed considerably. For instance we now eat more "out of season" and imported foods grown on a wide variety of soils from many different countries. Some of the fruits and vegetables have always been imported but many of those previously grown in the UK are also now imported. Storage and ripening systems have changed. Greenhouse crops are "brought on" more quickly now and often grown in soil-less mixes. Could these practices have changed the composition of fruits and vegetables?

The varieties of plants cultivated now has also changed. Nowadays we practise sophisticated plant breeding and have bred selectively for qualities that will suit the demands of, for example, high yield, post-harvest handling qualities and cosmetic appeal. Also we select varieties that will respond well to the methods of agriculture currently employed. Specific breeding to enhance nutritional quality is rare.

Agricultural practices

During the early 1930s agricultural chemicals were hardly used. Manure and compost were the main fertilizers used. After the war practices changed and farmers became more reliant on the use of fertilizers and other agrochemicals as well as heavy farm machinery.

Agriculture which relies on NPK fertilizers and pesticides, that adds little organic matter to the soil and that alternates between soil compaction and ploughing, could produce food depleted in minerals. These practices affect the structure, chemistry and ecology of the soil in ways that could affect the availability of minerals to plants and hence the mineral content of crops. For instance, mycorrhizal fungi have a symbiotic relationship with plant roots in which sugars and minerals are exchanged. The fungi are reduced by high levels of available phosphate and nitrogen, low pH, waterlogging or excessive dryness[5].

Another factor could be the differing levels of contamination of crops with residues of pesticides containing high concentrations of minerals – for example Bordeaux mixture contains high levels of copper and was widely used as a pesticide.

In principle, modern agriculture could be reducing the mineral content of fruit and vegetables. We need to find out if this, or any of the other explanations described above, are significant factors in practice. Considering the magnitude of the reductions this matter deserves urgent attention.

The following questions arise from the findings:

- Are the data reliable?
- Is the apparent decline caused by diminished levels of minerals in the soil, poor availability, the choice of cultivars or other changes in the food system?
- To what extent is the decline in minerals of importance to human nutrition?
- Are other countries experiencing similar changes?
- Are there similar reductions in other crops – such as cereals?

- Are other minerals of equal importance to human nutrition, such as Se and Cr, also reduced?
- Are other nutrients – for example, vitamins – also reduced?
- Are some cultivars producing crops that are lower in minerals than others?
- Does soil contamination – past or present – affect the mineral content of crops?

To answer these questions existing literature needs to be reviewed and further research carried out along the suggested lines;

- an analysis of the effect of the latest *Composition of Foods* data on usual diets;
- compilation of a database of historical data from different countries, different time scales and different crops;
- detailed and controlled studies of soils and the effects of methods of agriculture on plant nutrition and crop mineral content;
- studies of the mineral content of fruit and vegetables grown using different cultivars in common use now and 60 years ago;
- regular monitoring of food composition with details on cultivars, methods of growing and soils.

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