Dr. Firman Bear – Variations in vegetable mineral content

Introduction

The percentages of ash and of each constituent in the ash of any given species of plant are known to vary widely. They vary with the variety and with the age of the plant and the environmental conditions under which it was grown. As Sims and Volk have pointed out (9)[3], such variation is of considerable significance to animals and man, since these creatures depend upon plants for most of the mineral matter they require.

Recent studies of plant ash have confirmed Liebig's century-old concept (5) that "the species of one and the same family will contain the same number of basic equivalents combined with vegetable acids." This principle would now be stated as follows:

Under uniform conditions for growth, except for limited variations in the relative amounts of the several cations in the nutrient media, the sum of the Ca, Mg K, and Na, expressed in milliequivalents per unit weight of dry matter, is a constant for any given plant variety.

Recognition that this principle applies in plants was delayed because chemists have long been reporting analyses of plant ash in terms of percentages of the constituent elements, rather than as their equivalents. Within recent years, however, a number of workers have presented their data in equivalent form, and the principle has been adequately confirmed (2, 6, 7). The highest degree of constancy is found in the terminal leaves (10).

Although Ca is the dominant cation in the exchange complex of normal agricultural soils, its rate of movement into the plant is relatively slow in comparison with that of K. Thus, in an experiment with alfalfa (3), it was found that, with a Ca-K equivalent ratio of 32:1 in the exchange complex of the soil, the ratio of these cations in the plants which grew on that soil was only a little over 3:1. This tendency of plants to take up K is such that much larger amounts of it are often absorbed from the soil than are required for optimum crop yields. When this occurs, the absorption of Ca, Mg, and Na is correspondingly reduced. This may be to the disadvantage of the consuming animal and to man.

The principle of constancy also appears to apply to the mineral anions in plants. For example, Nightingale pointed out (8) that application of nitrate results in the reduction of phosphate uptake in pineapples. When soil fumigants were employed and the ammonia forms of nitrogen were not changed to nitrate for a considerable period of time, phosphate absorption was increased.

In a series of alfalfa plants that were grown in our greenhouse under standardized conditions, except for wide variations in the individual anion values in the nutrient media, the sums of the N, S, Cl, and P absorbed, per unit of dry matter, were essentially constant. It should be noted in this connection that the pH values of the nutrient media were kept uniform. This is important in both cation and anion studies that have to do with this point.

Percentages of ash and summation values are known to be subject to wide variations, depending upon the extent to which the dilution factor of carbohydrate production operates. They tend to be considerably higher in the irrigated arid and semi-arid regions than in the more humid regions. This is in conformity with Albrecht's concept of high-carbohydrate versus high protein-and-mineral vegetation regions of the United States (1).

It is apparent from the foregoing that the mineral cation and anion values in plants are an expression of the environment in which the plants were grown. The environmental factors that seem to exert the greatest influence are soil type, fertilizer practice, and climate.
Wide variation in these three environmental factors is readily found as one proceeds from south to north and from east to west in the United States. An opportunity was recently provided[4] to obtain samples of vegetables from a line of states extending northward from Georgia to New York (Long Island) along the Atlantic Coast and from another line of states that extended as far west as Colorado. It is the purpose of this paper to present the results of a study of the mineral composition of the vegetables so selected.

Experimental Work

Samples of cabbage, lettuce, snapbeans, spinach, and tomatoes were obtained from commercial fields of these crops in Georgia, South Carolina, Virginia, Maryland, New Jersey, New York (Long Island), Ohio, Indiana, Illinois, and Colorado.[5] The total number of samples examined was 204.

The collecting had to be done during the midsummer months, and this made it impossible to obtain samples of all five crops from all 10 states. Fortunately, samples of snapbeans and tomatoes were taken from every state. This report, therefore, deals primarily with the findings on these two crops. Bountiful snapbeans and Rutgers tomatoes were chosen for collecting and most of the samples belonged to these two varieties. So far as possible, the cabbage, lettuce, and spinach samples were confined to the Golden Acre, Grand Rapids, and Savoy varieties, respectively.

All samples were collected at the stage of growth when they were being harvested for market. Field collection was followed by as rapid transportation to the laboratory as possible. Only the edible portions were prepared for analysis, the outer leaves of cabbage and lettuce being discarded. All samples were rinsed in cold distilled water. The tomatoes were rubbed also with a clean cloth. The samples were dried in a hot-air convection oven at temperatures ranging between 70 and 80^{o} C. Samples of the vegetables were wet-ashed with a mixture of nitric and perchloric acids and made up to volume. Aliquots were then analyzed for the major nutrient elements by standard procedures, including the use of the flame photometer for determining Ca, K, and Na. Another sample was dry-ashed at between 600 and 700^{o}C and analyzed for the minor mineral nutrient elements by the use of a spectrograph.[6]

Characteristics of Soils on Which Vegetables Were Grown

The soils involved in the eastern coastal-plain states were of the Tifton, Bladen, Orangeburg, Portsmouth, Norfolk, and Sassafras series. These belong to the podzolic group, including both the red-yellow and the gray-brown zones. They have all been developed from coastal-plain materials and have been thoroughly leached, they have relatively low exchange capacities, and they contain only very limited supplies of mineral nutrients.

The soils involved in the east north-central states were of the Wooster, Miami, Crosby, Brookston, Clarion, and Webster series. The first four are members belonging to the gray-brown podzolic group, which have been developed on glacial drift, some of which was of a calcareous nature. Those of the last two series are prairie soils, which have been developed from calcareous glacial drift.

The Colorado vegetables were obtained from areas, where the Laurel, Gilchrist, and Berthan series predominate. These soils belong to the brown and planosol groups, and are under irrigation farming. They are high in calcium carbonate and in available mineral nutrients.

Fertilizer Practices in the Areas Involved

As Beeson has pointed out (4), fertilizing and liming practices influence the mineral composition of plants. Consequently it seemed desirable to make a survey of these practices as employed on the fields from which the samples were selected. The data from this survey are summarized in Table 1. It is important to note the relatively high rates at which fertilizer is applied in the coastal-plain states as compared to the rates employed farther west. In the east north-central states less dependence is placed on fertilizers and greater use is made of clover sods and manure. Only relatively small amounts of fertilizer are used in Colorado.

The rate of use of lime increases from Georgia northward to New Jersey. It varies considerably from farm to farm in the east north-central states. No lime was used on the Colorado farms.

Ash and Mineral Cation Content of Vegetables

Data on the ash and mineral cation content of 46 samples of snapbeans and 67 samples of tomatoes are shown, state by state, in Table 2. Summary values for all five vegetables are given in Table 3. After consideration of the state-average and summary values, in conjunction with the individual values for the 204 samples of all five vegetables, of which only the extremes are shown at the bottom of the table, the following conclusions were drawn:

1. Ash, Ca, and cation-equivalent values tend to increase from south to north and from east to west.
2. K values tend to increase from east to west.
3. Mg values tend to increase from north to south and from east to west.
4. Na values tend to decrease from east to west.[7]

Phosphorus and Minor Element Content of Vegetables

The P, B, Mn, Fe, Mo, Cu, and Co content of the same samples of snapbeans and tomatoes from all 10 states are shown in Table 4. Studies of these state average values, in conjunction with the 204 individual values, of which only the extremes are shown at the bottom of the table, permit of the following conclusions:

1. P values are relatively constant from state to state, but the individual values for each vegetable vary between wide extremes.
2. B, Fe, Mo, Cu, and Co values tend to increase from east to west.
3. Mn values tend to decrease from east to west.

Miscellaneous Observations

Wide variations were found from region to region in the percentage ash and of each of the individual mineral nutrient elements in the ash.

Wide variations were found in the cation-summation values. This is to be expected, since the environmental conditions under which the plants had been grown were very dissimilar.

Spinach was notably high in ash. Variations in K, Na, B, and Fe values were greatest in this plant. The K values varied between 10.05 and 3.31%, the Na values between 1.60 and 0.02%, the B values between 88 and 12 ppm, and the Fe values between 1584 and 19 ppm.[8] Spinach appeared to be an accumulator of both Mo and Co.

Tomatoes showed the greatest variation in Ca, Mg, and Cu. The Ca values varied between 0.40 and 0.09%, the Mg values between 0.72 and 0.14%, and the Cu values between 46 and 0 ppm.

Snapbeans grown in Ohio, Indiana, Illinois, and Colorado were notably high in Mo. The average Mo value for the four east north-central states and Colorado was 3.9 ppm, in comparison with 0.4 ppm for the six coastal-plain states. The highest Mo value, 24.1 ppm, was found in a sample of Indiana cabbage.

Lettuce and spinach were two exceptions in the general trend of higher Mn values in the eastern states than in the east north-central states and Colorado. The explanation for this probably lies in the fact that eastern soils are usually well limed for these crops. Often they are overlimed. The lowest Mn value, 0.6 ppm, was found in a sample of lettuce from New Jersey, and the highest, 161 ppm, in a sample from Indiana.

Colorado vegetables, in comparison with those from the other nine states, were relatively high in Co, Mo, Cu, and Ca in the order indicated. They were moderately high in K, Mg, Fe, and B, in the order indicated. They were about average in P, relatively low in Mn, and very low in Na.

The K content of Colorado vegetables was not as high relatively as one might expect. The explanation for this is found in the fact that the soils of Colorado are relatively very high in Ca and Mg, as well as in K. It is important to note also that liberal applications of K, in the form of fertilizers and manures, are made to the land in the east and south in preparation for growing vegetables. This is in marked contrast to the very small rates of application of such materials in Colorado.

This piece from www.midcoast.com.au/users/bec/orgfood.htm

Comparative analysis of the nutrient content of organic and non-organic food from the Firman Bear report, Rutgers University. The shaded rows are organic produce, unshaded rows are conventional produce.

Crop	Calcium	Magnesium	Potassium	Sodium	Thiamin	Iron	Copper
Snap Beans Organic	40.5	60	99.7	8.6	60	227	69
Snap Beans	15.5	14.8	29.1	<1	2	10	3
Cabbage Organic	60	43.6	148.3	20.4	13	94	48
Cabbage	17.5	15.6	53.7	<1	2	20	<1
Lettuce Organic	71	49.3	175.5	12.2	169	516	60
Lettuce	16	13.1	53.7	<1	1	9	3
Tomatoes Organic	23	59.2	148	6.5	68	1938	53
Tomatoes	4.5	4.5	58.6	<1	1	1	<1
Spinach Organic	96	203.9	257	69.5	117	1584	32
Spinach	47.5	46.9	84	<1	1	19	<1

Firman Bear report, Rutgers University, all numbers represent Milliequivalents per 100 grams, dry weight.

[Back to report]

Summary and Conclusions

Two hundred and four samples of cabbage, lettuce, snapbeans, spinach and tomatoes were analyzed for their content of ash, Ca, Mg, K, Na, P, B, Mn, Fe, Mo, Cu, and Co.

These samples were chosen from Georgia, Virginia, South Carolina, Maryland, New Jersey, New York (Long Island), Ohio, Indiana, Illinois, and Colorado.

Wide variations were found in the mineral content of vegetables of the same variety.

Ash, Ca, and cation-equivalent values tended to increase and Mg values to decrease from south to north.

Ash, cation-equivalent, Ca, Mg, K, B, Fe, Mo, Cu, and Co values tended to increase from east to west.

Na and Mn values tended to decrease from east to west.

P values tended to be relatively constant, but wide individual variations were found in the same variety of vegetable.

The greatest variations in K, Na, B, and Fe values were found in spinach.

The greatest variations in Ca, Mg, and Cu values were found in tomatoes.

Snapbeans from Ohio westward were relatively very high in Mo.

Colorado vegetables, in comparison with those from the other states, were relatively high in Co, Mo, Fe, Ca, K, Mg, Cu, and B, in the order indicated; about average in P; and relatively low in Mn and Na.

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Misquotes in "Variation in Mineral Composition of Vegetables"

A study conducted at Rutgers University (Bear et al., 1948) is frequently misquoted as evidence supporting the position that organically grown vegetables are significantly superior in minerals and trace elements to conventionally grown vegetables. In reviewing the original publication, one can clearly see that this was not the intention of the study nor does it give support to this premise. The purpose of the study was to compare the mineral composition of vegetables "as one proceeds from south to north and from east to west in the United States." Samples of cabbage, lettuce, snapbean, spinach, and tomatoe were obtained from commercial fields of these crops and analyzed for mineral composition. A total of 204 samples were examined. The vegetables sampled were usually, but not always, of the same variety. The authors reported, in a table, the range in mineral concentration as highest and lowest values observed among the vegetables sampled. These highest and lowest values have been misrepresented as vegetables grown organically and inorganically, respectively, in various organic farming and healthfood newsletters, which cite the report (copies of the misquotes are available on request).

The authors discussed the influence of soil type, fertilizer practice, and climate on the observed differences in mineral composition. The study only provides a general survey of their possible influence and did not compare synthetic fertilizer and organic practices.

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