*Variations in the trace element contents of some vegetables**

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It is the purpose of this paper to draw the attention of nutritionists, medical men, and epidemiologists to the wide variations that are to be found in the trace element concentrations in various vegetables. The concentrations in vegetables may vary widely depending on where they are grown. Furthermore, vegetables differ among themselves in their ability to incorporate specific elements from their environment. These differences in the trace element concentrations in vegetables are far greater than has previously been generally realized.

I do not wish to trespass into fields that properly belong to other disciplines. Nevertheless, thanks to the advice and knowledge provided by many workers in related fields, it is felt proper to draw attention to some relationships between trace elements and disease patterns which, although statistically inconclusive, nevertheless appear to justify further and more critical investigations.

History

In British Columbia, biogeochemistry has proved to be a useful tool in hunting for ore bodies buried beneath a mantle of overburden.

On carrying out various biogeochemical investigations, it was impressive to see how great were the variations between the trace element concentrations in different species of trees growing in a similar environment, and also between the concentrations found in one species of tree growing in different environments. Concentrations of a specific element in a particular species of tree or lesser plant commonly may vary by as much as one order of magnitude, and extremes of two orders of magnitude are by no means rare.

As examples, the following may be of interest. The ash of fireweed (*Epilobium angustifolium*) normally carries 50 to 100 parts per million of molybdenum: over one well-known molybdenum ore body in British Columbia, the fireweed contained 17,000 parts per million of that element in its ash. The ash of two year old stems of Douglas Fir, (*Pseudotsuga menziesii*) normally carries 40 parts per million of lead. However, in an appropriate environment as much as 2,000 parts per million are to be found. Other examples could be given involving such diverse elements as zinc, mercury, cadmium, manganese and gold.

It was observations such as these that prompted investigations into the varying concentrations of trace elements that might be found in vegetables.

So far the work does not justify the presentation of statistically sound data as far as normal values are concerned. It is hoped to establish normal values for particular vegetables growing in a recognizable environment. This is, therefore, a "reconnaissance in force".

Methods of collection and preparation

Various vegetables mature at different times and their trace element concentrations vary during the growing season. Our resources made it impractical for us to collect vegetables throughout the year. Our own collections were supplemented by others made by the generous co-operation of too many people to mention.

Widely representative samples of all the more important vegetables growing in various gardens were collected. British Columbian samples were immediately placed in an ice-box and within a few days, seldom more than a week, were delivered to our laboratory. British samples were delivered as promptly as possible to one of the laboratories who kindly consented to prepare the samples for shipment to Canada.

Each vegetable sample was prepared as it would be by a "prudent housewife". This meant

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that young potatoes or carrots were scraped and older ones peeled. Lettuces and cabbages were stripped of their outer leaves and carefully washed with tap water—to see what people were being given to eat.

After the vegetables were prepared, as they would be for consumption, they were oven-dried at approximately 60 deg. C, until they were dry enough to be milled in a small Wiley Mill. From one to five grams of the milled material were then ashed overnight at 550 deg. C.

If practical, the 'wet' or natural vegetable was weighed and also the resulting oven-dried material, and likewise the ash obtained therefrom. In this way we are able to make crude comparisons between the trace element content of ashed, oven-dried, or of wet vegetable. Various writers report their results differently—in parts per million (ppm)—of ash, of oven-dried, or 'wet' material.

Analytical notes

Vegetable ash is dissolved in a small excess of 3N hydrochloric acid which is evaporated to near dryness. The residue is taken up with a few drops of 3N hydrochloric, then with water, and made up to 30 ml. Aliquots are taken to determine various elements. Most determinations were done by atomic absorption with frequent checks by colorimetry. Any results not in reasonable agreement were repeated.

Summary of results

As can be seen from table I, only from 75 to 200 samples of each vegetable have been directly involved in this preliminary attempt to establish what may be considered to be "normal" However, many hundreds of other samples have been similarly treated, and it may be stated that they have all fallen within the ranges given for each particular vegetable.

Virtually all the samples came from Great Britain and British Columbia but a few originated in Ontario, Quebec, and Nova Scotia, and some from Wisconsin and Idaho, U.S.A.

TABLE I

THE RANGES AND SUGGESTED NORMALS FOR THE COPPER, ZINC, LEAD AND MOLYBDENUM CONTENTS OF SOME VEGETABLES (IN ppm. OF ASH)

Vegetable	*Approximate no. of samples*	*Copper*		*Zinc*		*Lead*		*Molybdenum*	
		Range	*Normal*	*Range*	*Normal*	*Range*	*Normal*	*Range*	*Normal*
Lettuce	200	4–480	60	70–6300	400	2–620	20	·6–60	5
Cabbage	75	7–100	40	140–1850	300	2–40	16	1–250	30
Potato	150	11–390	100	140–1500	320	4–620	40	1–120	16
Bean (except broad)	75	40–250	100	200–1160	450	6–130	30	2–430	60
Carrot	100	8–180	70	120–3800	450	5–330	30	1–290	30
Beet	90	10–190	80	180–5150	420	6–180	20	1–14	4

TABLE II

"WET", OVEN DRY AND ASH RELATIONSHIPS FOR SOME VEGETABLES

Vegetable	*A. Dry weight as percentage of wet weight*		*B. Ash as percentage of dry weight*	
	Between 75 per cent and 85 per cent fall between	*Working average*	*Between 75 per cent and 90 per cent fall between*	*Working average*
Lettuce	*4–10*	*6·5*	*15–20*	*19·0*
Cabbage	*4–10*	*7·0*	*8–11*	*9·3*
Potato	*15–20*	*19·5*	*4–6*	*4·7*
Bean (except broad)	*7–14*	*11·0*	*5–9*	*7·3*
Carrot	*8–14*	*11·0*	*5–8*	*6·8*
Beet	*8–14*	*11·5*	*7–10*	*8·5*

It was not always practical to obtain wet and oven dry weights for all vegetables. However, in all cases we have recorded ash and oven dry weights for each vegetable. The relationships between wet and oven dry weights will vary considerably depending on many factors such as the weather, and the time of harvesting. Accepting these most serious limitations, table II lists the ranges and "working averages" for relating "wet", oven dry, and ash contents of vegetables.

If we combine the data presented in tables I and II we are able to present in table III, as a working hypothesis, the normal trace element contents of the vegetables under consideration, both in terms of ash and of wet weights.

The above data are interesting in that they show a tendency for some elements to be higher in some vegetables than others. For example, beans appear to have a greater affinity for molyb-

TABLE III

THE TENTATIVE "NORMAL" COPPER, ZINC, LEAD AND MOLYBDENUM CONTENTS OF SOME VEGETABLES IN TERMS OF "WET" AND ASH WEIGHTS. (in ppm.)

Vegetables	*A. Ash weight*				*B. "Wet" weight*			
	Cu.	*Zn.*	*Pb.*	*Mo.*	*Cu.*	*Zn.*	*Pb.*	*Mo.*
Lettuce	60	400	20	5	0·74	4·9	0·25	0·06
Cabbage	40	300	16	30	0·26	1·9	0·10	0·20
Potato	100	320	40	16	0·92	2·9	0·40	0·15
Bean (except broad)	70	450	30	60	0·56	3·6	0·24	0·48
Carrot	70	450	30	30	0·52	3·4	0·22	0·22
Beet	80	420	20	4	0·78	4·1	0·20	0·04

TABLE IV

EXTREME DEVIATIONS FROM "NORMALS" BY COPPER, ZINC, LEAD AND MOLYBDENUM IN SOME VEGETABLES

	"Normal" content in ppm. wet weight	*Minimum as fraction of "normal"*	*Maximum as multiple of "normal"*	*Extreme range*
A. Copper				
Lettuce	0·74	1/15	8	1 to 120
Cabbage	0·26	1/6	2·5	1 to 15
Potato	0·92	1/9	4	1 to 36
Bean (except broad) ..	0·56	2/5	2·5	1 to 22
Carrot	0·52	1/9	2·5	1 to 22
Beet	0·78	1/9	2·5	1 to 20
B. Zinc				
Lettuce	4·9	1/6	15	1 to 90
Cabbage	1·9	1/2	6	1 to 12
Potato	2·9	1/2	5	1 to 10
Bean (except broad) ..	3·6	1/2	2	1 to 4
Carrot	3·4	1/2	8	1 to 48
Beet	4·1	1/4	12	1 to 16
C. Lead				
Lettuce	0·25	1/10	30	1 to 300
Cabbage	0·10	1/8	2·5	1 to 20
Potato	0·40	1/10	15	1 to 150
Bean (except broad) ..	0·24	1/5	4	1 to 20
Carrot	0·22	1/3	9	1 to 27
Beet	0·20	1/6	11	1 to 66
D. Molybdenum				
Lettuce	0·06	1/8	12	1 to 96
Cabbage	0·20	1/30	8	1 to 240
Potato	0·15	1/16	7·5	1 to 120
Bean (except broad) ..	0·48	1/30	7	1 to 210
Carrot	0·22	1/4	3·5	1 to 14
Beet	0·04	1/30	10	1 to 300

denum than do other vegetables, while potatoes tend to have more copper and lead than do other vegetables.

However, what would, at least superficially, appear to be of even greater importance are the unexpectedly wide divergences from the "normal" that may be encountered in most of the vegetables under discussion.

Table IV expresses these deviations from 'the normal' in terms of fractions and multiples. An extra column is introduced which emphasizes the extreme ranges of concentrations that have so far been encountered for each element and vegetable.

We do not know if an individual would be harmed by ingesting normal quantities of vegetables containing some of the more extreme concentrations of those elements listed. However, doses of ten times—one order of magnitude—the normal intake of some elements, such as arsenic, cadmium, and mercury are not likely to be inducive to good health. Moreover, it is widely known that only modest increases in the intake of some elements such as selenium, molybdenum and lead, can be harmful to animals. Could it be that our diets, complicated because they come from many sources, hold clues to some human health problems?

Recent descriptions of Minamata disease (mercury) and Itai-Itai disease (cadmium) are exceptional, but consideration of an old problem, that involving lead, may show that these facts deserve to be investigated more fully.

Lead in food

It appears that from 0·3 to 0·4 milligrams are ingested daily from air, water, and food. Food supplies most of this lead; air and water only contributing significantly in special circumstances.

A person might well consume 100 grams (a little less than four ounces) of potatoes during one day. If this potato contained a "normal" amount of lead, *ie*, 0·4 ppm, this person would ingest 0·04 mg of lead. However, if the data presented in table IV are correct, then our individual could receive from his helping of potato as little as 0·004 mg of lead, or as much as 0·6 mg. This latter amount is 50 per cent above the normally accepted intake. Moreover, all this would be without taking into account the lead that might be ingested in other food consumed.

Possible relationships between diseases and trace elements

Medical men have from time to time drawn attention to localities where there are thought to be an unusual incidence of some disease, such as multiple sclerosis and stomach cancer. In about a dozen such localities we have been able to obtain collections of vegetables. In at least 75 per cent of the localities where the prevalence of multiple sclerosis appeared to be above normal, lead was found in higher than "normal" amounts in vegetables. In some instances, the presence of this lead has neither been expected nor explained. However, lead cannot always be incriminated. Unusual concentrations of molybdenum were quite unexpectedly found in several areas where unusual concentrations of multiple sclerosis or cancer were reported. Abnormal concentrations of zinc also occur in some supposedly disease-prone areas.

Attempts to correlate trace elements and epidemiology are at present speculative and must be left until more thorough and well integrated studies are completed. Evidence that is available does suggest that such studies might prove rewarding.

Some causes of anomalous areas

The rocks and the soils of the earth's crust vary widely in their content of major and minor elements. This is often reflected in the trace elements found in the vegetables growing in specific areas.

It is one of the facts of life that civilization, as we know it today, is built on metals: without metals our civilization could not survive. Food, shelter, clothing, transportation, communication, and above all energy, are dependent on metals; almost any one of which, if present in air, water, or food in too great or, possibly rarely, too small amounts, can lead to ill health.

Many factors such as climate, weather, and topography contribute to anomalous trace-element concentrations in food; background geology and man's activities are among the principal factors. In connection with man's activities, the world is undergoing a population explosion the like of which has never before occurred. Every seven years 500 million people are being added to the world's population—a number equal to the people inhabiting the whole globe at the time of Elizabeth I. Furthermore, each individual is using three times as much copper, lead, and zinc as he was only 50 years ago, and some elements, such as molybdenum, have only come into general use during this time.

In addition, more and more people are leaving rural areas and moving into urban communities. Thus, while popular attention has been drawn to industrial contamination, I have found that general urban contamination is equally serious; indeed there is no clear dividing line between the two. One expects to find vegetables with anomalous copper growing in the vicinity of Sudbury and Noranda, where copper ores are smelted. However, it is surprising that equally high copper contents are found in vegetables growing in Liverpool, Birmingham, Jersey, and an area in rural Nova Scotia.

Similarly one could expect to find vegetables with anomalously high zinc contents growing near Trail, Noranda, and Riondel where zinc ores are mined or smelted. However, equally high zinc contents are found in vegetables growing in a section of residential Vancouver, in Birmingham, Bradford, Leeds, and Liverpool.

It is possible to provide many more examples both of expected and unexpected localities where anomalous vegetables may be found; two more are enough.

Anomalously high molybdenum-bearing vegetables are found in Trail—a great lead-zinc metallurgical centre—Oyama—a small rural agricultural area in British Columbia—and south-west Devonshire, in an old mining area which has not been known to produce any molybdenum. By way of contrast, Trail is not marked by having unusually high lead in vegetables grown in the vicinity. Amongst those districts contributing the highest lead-bearing vegetables are sections of North Wales, south-west Devon, north-west Nova Scotia, Jersey, and the communities of Liverpool and Noranda.

Summary

Variations in the trace element concentrations of vegetables are far greater than are generally realized. The range in concentrations is frequently of one order of magnitude and occasionally as great as two orders of magnitude.

Anomalous concentrations are found not only in rural areas but in industrial, and urban communities. Indeed they are so widespread that if trace elements are significantly related to human health, then these facts are of concern to virtually all nutritionists, clinicians, and epidemiologists.

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