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HortScience 24(2):338–340. 1989.

Element Concentration in Layers of Table Beet Roots and in Various Beet Cultivars

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Additional index words. *Beta vulgaris*, minerals, soil analysis, peel, flesh, core

Abstract. **The concentration of mineral elements from the outer peel to the core of five table beet (*Beta vulgaris* L.) cultivars was determined by separating roots into five fractions. Soil contamination was important only in affecting the concentration of Fe in the outer peel. Mineral element concentration was highest in the outer peel, decreasing by about one-half in the inner peel. Some mineral element differences are noted among cultivars.**

The mineral content of root tissues is related to tissue function (8), and is of interest because of human nutritional considerations (7). Earlier studies showed that the concentrations of selected elements in raw beet roots were slightly different from concentrations in peeled roots (11). These differences suggested a variation in composition between the peel layer and the rest of the root. Others have found that Pb was higher in beet root cortex tissue, whereas Pb was lower in turnip root cortex (9). Mineral variations have been found in the organs of other plants. The peel of potatoes has twice the ash concentration of peeled potatoes (7), with Ca, Fe, and Mn being particularly high in the peel (2, 4). Apple skins were higher in Ca, Mg, and Fe than the flesh (6). Such distributions have significance in human mineral nutrition because the peels are frequently removed before consumption.

We found no published data that clearly show the composition of the peel layer of vegetables with respect to mineral elements and, at the same time, make correction for possible soil contamination. The object of this study was to compare the element composition of beet root regions from the outer peel to the core in five table beet cultivars.

Five beet cultivars were grown in each of two locations near Geneva, N.Y. The soil type at both locations was Lima silt loam (fine-loamy, mixed, mesic Glossoboric Hapludalf). Roots, dug in early September, had considerable variation in size within each cultivar ('Detroit Dark Red', 'Fire Chief', 'Gladiator', 'N. V. 103', 'Ruby Queen') and location. Five roots of similar size for each cultivar–location were selected for analysis. This gave 10 lots of beets. The selected beet roots had an average diameter of 73 mm, SD = 8 mm.

Table 2. Average[z] concentration of fine particle[y] mineral elements for soils in which beets were grown. (Dry weight basis)

Element	Concentration (ppm) ± SE
Fe	20400 ± 428
K	15900 ± 558
Na	7980 ± 218
Mg	4560 ± 248
Ca	6730 ± 88
Ti	2360 ± 22
P	1210 ± 61
Ba	395 ± 14
Mn	604 ± 56
S	254 ± 32
Zn	75 ± 2
Cu	21 ± 1
Ni	20 ± 1
Mo	11 ± 1
Cd	6 ± 3

[z]Means of analysis of soils from two locations.
[y]Particles <5 μm in diameter plus soluble soil components (5).

Table 1. Description of beet root fractions.[z]

Fraction	Fraction of beet roots (%)		Dry wt[y] in each fraction (%)
	Wet-wt basis	Dry-wt basis	
Outer peel	5.3	5.8	16.1 a
Inner peel	4.4	5.1	17.0 b
Outer intermediate	40.6	42.5	15.2 c
Inner intermediate	23.3	21.9	13.7 d
Core	26.5	24.7	13.6 d

[z]Averages for five cultivars and two locations.
[y]Means not followed by the same letter were significantly different at $P < 0.05$ by Duncan's multiple range test.

Received for publication 1 Feb. 1988. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Table 3. Average element composition of dry fractions of beet root.[z]

Fraction	Macroelements (%)						Microelements (ppm)			
	N	P	K	Na	Ca	Mg	Zn	Mn	Fe	Cu
Outer peel	2.67 a	0.435 a	5.43 a	0.171 a	0.336 a	0.499 a	40.1 a	47.6 a	203.3 a	16.61 a
Inner peel	2.01 b	0.302 b	2.08 d	0.076 c	0.197 b	0.195 b	20.8 b	22.8 b	40.9 b	5.79 b
Outer intermediate	1.57 d	0.189 c	2.46 c	0.077 c	0.096 c	0.119 c	13.5 d	17.7 c	18.0 c	3.74 c
Inner intermediate	1.70 cd	0.191 c	3.44 b	0.091 b	0.083 c	0.150 bc	14.7 d	18.0 c	19.3 c	4.86 bc
Core	1.75 c	0.205 c	3.52 b	0.087 bc	0.090 c	0.182 b	18.5 c	19.6 c	19.1 c	5.32 b
All trimmed beets	1.73	0.21	3.09	0.088	0.111	0.167	17.0	20.4	30.6	5.26

[z]Means in columns not followed by the same letter were significantly different at $P < 0.05$ by Duncan's multiple range test. Averages for five cultivars and two locations.

Roots were trimmed by removing the tops plus 1 cm of the main body of the root and the tap root plus 1 cm of the main body of the root. The trimmed roots were washed in tap water, using a soft brush to remove soil. After soil removal the trimmed roots were rinsed with distilled water. The average weight of the trimmed, washed roots was 151 g, SD = 28 g.

Five fractions were obtained from the roots. From the outside inward, these fractions were designated as outer peel, inner peel, outer intermediate, inner intermediate, and core. The peels were removed with a hand vegetable peeler. Each of the peel thicknesses was 0.9 mm. The other fractions were obtained from 15-mm-thick slices cut from the center of the peeled root perpendicular to the root axis. In calculations of variety values, the relative proportions of these last three fractions were assumed to hold true for the remainder of the trimmed, peeled roots. The fraction samples from the separate cultivars and locations were freeze-dried and ground for the elemental analysis.

Elemental analysis of the ground samples was carried out using atomic absorption spectrometry and the micro-Kjeldahl method (12). Additional elemental analysis, including that for Ti, was carried out on the 'Ruby Queen' samples using the ICP method of Cary et al. (3). This ICP procedure was also used for analysis of soil particles <5 μm in diameter (5). The differential Ti content values were used to estimate soil contamination in the beet fraction samples (3). Because Ti values indicated (3) <0.6% soil contamination (dry basis) in the outer peel fractions, no corrections for soil contamination were applied to the beet fraction elemental analysis.

Statistical analysis was done using the SAS statistical package for the analysis of variance.

Wet and dry weight characteristics of the fractions are described in Table 1. The relative dry weight was higher in the outer fractions. Analysis of small soil particles (Table 2) shows that Fe was an important component, comprising ≈2% of this soil fraction.

Titanium assay of the various beet fractions from 'Ruby Queen' indicated that <0.6% of the outer peel on a dry-weight basis was soil (3). The only element showing a major correction is Fe (Table 2). The outer peel Fe concentration for 'Ruby Queen' corrected for soil content would be 47 ppm instead of 168 ppm. Applying this correction to the average Fe concentration in the outer peel of all beets reduced the average Fe concentration from 203 ppm to 81 ppm. This value still is significantly higher than that for any other portion (Table 3). Based on Ti concentration, the four inward fractions averaged 0.016% soil on a dry-weight basis, corresponding to 3 ppm of Fe in the dry fraction.

Element analysis showed significant differences in the composition of the various fractions (Table 3). All of the elemental concentrations were highest in the outer peel. For K, Na, Mg, Zn, Mn, Fe, and Cu, the inner peel concentrations were half or less than that in the outer peel. With the exceptions of K, Na, and Ca, the lowest concentrations were in the outer intermediate fraction, although this concentration was not always significantly different from the concentration in the inner intermediate or core fraction.

Correlations between element concentrations within fractions were rather irregular. The most consistent correlation was seen for Mg × Zn, which was significant at $P < 0.05$ for four fractions and had a P value of 0.12 in the outer intermediate fraction. The correlations of N × P were significant for three fractions and averaged, over the five fractions, 0.67, with an average P value of 0.04. The inner peel showed 14 significant correlations out of a possible 45, whereas the other four fractions averaged five significant correlations per fraction.

Concentrations of Ba, Cd, Mo, Ni, and S found in the various fractions of 'Ruby Queen' are shown in Table 4. The concentrations of Cd, Mo, and Ni were near the detection limit in the samples analyzed. The concentrations of Ba and S in the various fractions followed the same general relationships as seen with the elements shown in Table 3.

The mean concentration of P in 'Ruby Queen' was significantly greater than in the other cultivars (Table 5). Sodium concentration was lowest in 'Fire Chief' and highest in 'Detroit Dark Red'. Calcium concentrations were significantly lower in 'N. V. 103' than in the other cultivars. Copper concentration was significantly higher in 'Detroit Dark Red'. The concentrations of N, K, Mg, Zn, and Fe were similar in the five cultivars.

Table 4. Microelement concentration (ppm) in 'Ruby Queen' table beets on a dry-weight basis (ICP method).[z]

Fraction	Element				
	Mo	Ni	Ba	Cd	S
Outer peel	0.31 ab	0.94 a	43 a	0.57 a	1690 a
Inner peel	0.45 a	1.51 a	26 b	0.35 a	986 b
Outer intermediate	0.28 ab	0.57 a	24 b	0.09 a	728 b
Inner intermediate	0.12 bc	0.41 a	26 b	0.16 a	669 b
Core	0.02 c	0.66 a	29 b	0.36 a	770 b

[z]Means in columns not followed by the same letter were significantly different at $P < 0.05$ by Duncan's multiple range test.

Table 5. Comparison of elemental composition on a dry-weight basis in trimmed roots of several beet cultivars.[z]

Cultivar	Macroelements (%)						Microelements (ppm)			
	N	P	K	Na	Ca	Mg	Zn	Mn	Fe	Cu
Detroit Dark Red	1.80 a	0.207 b	3.33 a	0.109 a	0.119 a	0.166 a	18.2 a	17.1 b	32.4 a	6.6 a
Fire Chief	1.72 a	0.195 b	2.90 a	0.068 b	0.115 a	0.163 a	16.8 a	20.5 ab	31.5 a	5.2 b
Gladiator	1.51 a	0.201 b	2.97 a	0.085 ab	0.108 a	0.161 a	16.2 a	25.3 a	30.3 a	5.0 b
N. V. 103	1.85 a	0.216 b	2.90 a	0.074 ab	0.094 b	0.162 a	16.2 a	16.4 b	34.0 a	4.9 b
Ruby Queen	1.75 a	0.247 a	3.28 a	0.101 ab	0.117 a	0.181 a	16.7 a	21.9 ab	23.9 a	4.3 b

[z]Means in columns not followed by the same letter were significantly different at $P < 0.05$ by Duncan's multiple range test. Averages for two locations.

The mineral concentration variations among cultivars were similar to that seen earlier for one cultivar (Ruby Queen) grown at four widely separated locations (11). Carrot cultivars have greater variation in root mineral content (1) than seen for beets in the present study.

High mineral concentrations in the beet root outer peel were consistent with the high amounts of apoplastic tissue in this layer. The concentrations of N, K, Mg, Ca, and Mn were similar to those found in highly apoplastic beet leaf petioles (10). A similar combination of high mineral concentrations with apoplastic tissue was seen in potato tuber cortex (4). The outer peel concentration of Fe was closer to that in leaf blades than other plant parts. The outer peel had more P and less Na than beet petioles or blades.

The variations in mineral content in different root layers have nutritional importance because peeling removes proportionally more minerals on a volume basis. Beet cultivar had little effect on root mineral composition. As yet there is no information on the relation of root size to mineral distribution.

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HortScience 24(2):340–342. 1989.

Changes in Acidic and Basic Peroxidase Activities during Tomato Fruit Ripening

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Additional index words. *Lycopersicon esculentum*, IAA oxidase, ACC oxidase

Abstract. **Activities of the acidic and basic peroxidases from tomato fruit (*Lycopersicon esculentum* Mill. cv. Flora Dade) were determined at six ripening stages, from green to red-ripe fruits. Both the acidic and basic peroxidases reached a maximum during the climacteric, at the pink stage, but the relative increase in basic peroxidase activity was much more pronounced. Changes in the peroxidase, IAA oxidase, and ACC oxidase activities of the basic peroxidases paralleled the changes in ethylene production. However, in the presence of calcium, the degree of activation of peroxidase was constant throughout ripening, whereas the IAA and ACC oxidase activities of the basic peroxidases were only activated at the pink stage.**

Changes in peroxidase (EC 1.11.1.7) activity during fruit ripening have been the subject of many studies (2, 5, 6, 14), with total peroxidase (4) or the different peroxidase fractions, mainly soluble and ionically bound fractions being the areas investigated (2, 6, 14). Electrophoretic studies with tomato fruit indicate that fractions consist of different isozymes whose activities change according to the developmental stages of the fruits (14). Since isozymes have very different affinities toward substrates and are inhibited by an excess of substrate [either the hydrogen peroxide or the hydrogen donor (3)], the exact evaluation of the real peroxidase activity of a crude extract is almost impossible. Thus, little is known of the quantitative changes in the activities of peroxidase isozymes during fruit ripening. However, such information is important because the two main forms present in plants, the acidic and the basic peroxidases, exhibit different substrate specificities and physiological roles (4). Among these roles, the basic form may be involved in the degradation of IAA (4) and the conversion of ACC to ethylene (1, 4). In the present investigation, we report on the changes during tomato fruit ripening of the total, acidic and basic peroxidase activities and of the 1*H*-indole-3-acetic acid (IAA) and 1-aminocyclopropane-1-carboxylic acid (ACC) oxidase activities of the basic peroxidases. These determinations were performed on naturally ripened tomato fruits thoroughly characterized by their CO_2 and ethylene production rates, firmness, and pigment content.

Field-grown 'Floradade' tomato fruits were harvested and segregated into the following six ripening stages: green, G; mature green, MG; breaker, B; pink, P; orange red, OR; and red ripe, RR. Ethylene production and respiratory rate were determined on three fruits for each ripening stage 28 hr after the fruits were picked. Ethylene and CO_2 measurements were carried out as described by Nicolas et al. (10). Pulp firmness (residual force after 1-cm penetration of a 3-mm-diameter tip) was measured, as described by Nicolas et al. (9), on 40 fruit for each ripening stage. The same 40 fruits were then used to constitute eight sub-samples of five fruits for each ripening stage; the fruit were immediately prepared by dicing, blending, deep-freezing, and grinding in liquid N_2 and storing at −20C for lycopene and peroxidase analysis.

The lycopene content was determined spectrophotometrically according to Lime et al. (8).

Peroxidase was extracted as follows: 3.5 g NaCl was added to 60 g of tomato powder and the suspension was homogenized for 90 min at 4C in a rotary agitator. The resulting tomato homogenate was then centrifuged at 40,000× *g* for 15 min. The filtered supernatant is referred to as the crude extract. Each

Received for publication 11 Apr. 1988. This work constitutes a partial fulfillment of the requirements for the PhD of C. Rothan. We thank F. Gauillard and F.X. Sauvage for skillful technical assistance. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.