flavor scores (Dougherty and Fisher, 1977), the utility of the Davis test as a predictive measure of grapefruit bitterness is not without question.

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Effect of Potato Virus X on the Mineral Content of Potato Tubers

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The effect of infection with potato virus X (PVX) on the mineral content of five potato cultivars was studied. The cultivars, Katahdin and Chippewa, were grown during the first season, and Katahdin, Chippewa, Sebago, Peconic, and Bake King were grown during the second season. Tubers from plants that were infected with PVX were compared for mineral composition with those that were free of the infection. Infection with PVX resulted in a decrease in Ca, Fe, and Cu and an increase in P and Zn as compared with the controls. No significant changes were found in K, Mg, Mn, B, and Al content. Cultivars differed in their response to PVX. However, within cultivars there were consistent trends during each of the 2 years of the study.

Fresh potatoes are a good source of minerals. A 150-g serving of fresh potatoes will furnish 10% of the U.S. Recommended Dietary Allowance for iodine, 8% for copper and magnesium, 6% for phosphorus, and 2% for iron and zinc (True et al., 1978, 1979). Potato virus X (PVX) is an important virus affecting potatoes, and several researchers have reported an appreciable reduction in tuber yield with PVX infection (Emilsson and Gustafsson, 1956; Wright, 1970, 1977; Dowley, 1973). All the older varieties commonly grown in the United States and Canada such as Green Mountain, Irish Cobbler, and Russett Burbank are usually infected with this virus (Smith, 1977). Previous work from our laboratory has indicated that PVX-infected potatoes as compared to PVX-free potatoes are more susceptible to enzymatic discoloration, lower in crude lipid and phospholipids, and higher in phenols (Mondy and Koch, 1978). Differences in ultrastructural characteristics have also been shown between PVX-free and PVX-infected potatoes (Mondy et al., 1980). However, relatively little is known concerning the changes in mineral composition of potato tubers due to PVX infection.

Kozlowska (1964) reported that PVX infection of potatoes resulted in a higher level of potassium content. Tubers of virus X infected plants contained an average of 18% more potassium than tubers of healthy plants (Slusarek, 1971). Slusarek also found that infection with virus X increased the potassium content of potatoes in the initial stages of their development, and the level of potassium decreased significantly toward the end of the vegetation period. Phosphorus is one of the chief components of nucleic acid which forms the framework of the virus particle, and phosphorus has been shown to be absorbed more rapidly by diseased plants (Kozlowska, 1963). Panjar (1960) reported higher amounts of phosphorus in PVX-infected potato sprouts. Accumulation of phosphorus in PVX-infected tomato fruit has also been reported (Singh and Mall, 1973). Wynd (1943) reported that virus diseases decreased the calcium content of plant tissues. Bergman

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Table I. Macromineral Composition of PVX-Free (X−) and PVX-Infected (X+) Potatoes for Year 1[a]

variety, treatment	% dry wt			
	K	P	Ca	Mg
Katahdin, X−	2.74 ± 0.095	0.17 ± 0.005	0.04 ± 0.005	0.11 ± 0.005
Katahdin, X+	2.51 ± 0.250	0.22 ± 0.005	0.04 ± 0.017	0.12 ± 0.025
significance	NS	$p < 0.005$	NS	NS
Chippewa, X−	2.38 ± 0.100	0.16 ± 0.020	0.11 ± 0.050	0.09 ± 0.010
Chippewa, X+	2.48 ± 0.320	0.19 ± 0.005	0.13 ± 0.055	0.09 ± 0.005
significance	NS	NS	NS	NS

[a] All data are expressed as mean ± SE. NS represents not significant.

Table II. Macromineral Composition of PVX-Free (X−) and PVX-Infected (X+) Potatoes for Year 2[a]

variety, treatment	% dry wt			
	K	P	Ca	Mg
Katahdin, X−	2.15 ± 0.120	0.18 ± 0.010	0.036 ± 0.005	0.095 ± 0.004
Katahdin, X+	1.96 ± 0.025	0.26 ± 0.015	0.033 ± 0.001	0.100 ± 0.003
significance	NS	$p < 0.05$	NS	NS
Chippewa, X−	2.17 ± 0.070	0.16 ± 0.019	0.039 ± 0.012	0.154 ± 0.047
Chippewa, X+	2.55 ± 0.080	0.22 ± 0.015	0.020 ± 0.000	0.137 ± 0.044
significance	NS	NS	NS	NS
Sebago, X−	2.55 ± 0.080	0.17 ± 0.005	0.035 ± 0.001	0.149 ± 0.076
Sebago, X+	2.34 ± 0.015	0.19 ± 0.005	0.018 ± 0.003	0.164 ± 0.068
significance	NS	NS	$p < 0.05$	NS
Peconic, X−	2.02 ± 0.045	0.15 ± 0.005	0.036 ± 0.005	0.152 ± 0.069
Peconic, X+	2.10 ± 0.024	0.18 ± 0.005	0.020 ± 0.001	0.155 ± 0.067
significance	NS	$p < 0.10$	$p < 0.10$	NS
Bake King, X−	1.97 ± 0.024	0.17 ± 0.010	0.033 ± 0.001	0.153 ± 0.072
Bake King, X+	2.05 ± 0.075	0.18 ± 0.000	0.019 ± 0.002	0.159 ± 0.057
significance	NS	NS	$p < 0.05$	NS

[a] All data are expressed as mean ± SE. NS represents not significant.

and Boyle (1962), however, reported that virus infection influenced only slightly the contents of potassium, phosphorus, calcium, magnesium, and boron but significantly decreased copper and zinc in tomato plants.

The present investigation was undertaken to study the effect of infection with PVX on the mineral composition of potato tubers.

MATERIALS AND METHODS

The potatoes used in this study were grown during each of two successive seasons at the Uihlein Vegetable Research Farm of Cornell University at Lake Placid, NY. Potatoes of Katahdin and Chippewa cultivars were grown during the first year. During the second year, Katahdin and Chippewa cultivars were repeated, and three other varieties, Sebago, Peconic, and Bake King were also added. PVX-free and PVX-infected tubers were planted in a field plot by using a randomized block design. The cut seeds were planted by hand using 30-cm spacing and then covered immediately by a tractor-mounted hiller. Following a growth period of 104 days, the vines were removed by cutting with a corn knife to leave a 10–12-cm stubble. Five or six days following the cutting the remaining stubble was sprayed with Dow General. PVX-free seed was screened on *Gomphorena globosa* each year prior to planting, and in addition, a random check of plants was made during each growing season to assure freedom from PVX.

PVX-free and PVX-infected potatoes were planted on the same day, and the vines were sprayed with the vine killer on the same day and harvested on the same day to control the experiment. The tubers were stored at 4–5 °C for 4 months prior to analysis and were screened for PVX at the time of analysis.

PVX-free tubers were compared with PVX-infected tubers in each variety. Tubers of comparable size were selected for mineral analyses. The potatoes were cut longitudinally from bud to stem end in order to obtain equal sampling of both ends and were separated into cortex and pith sections. Cortex tissue including the periderm was used in the study, since this is the area of highest metabolic activity.

Mineral Analysis. Freeze-dried potato powder was analyzed for mineral content by using the photoelectric spectrometer technique as described by Kenworth (1960). Except for cadmium, duplicate determinations were made on each treatment in each of the 2 years of the study. Cadmium was analyzed only during year 2.

RESULTS AND DISCUSSION

Macrominerals. The effect of PVX infection on the macromineral composition of potatoes grown during year 1 is summarized in Table I. No significant difference in the quantity of potassium, calcium, and magnesium was found between PVX-infected and PVX-free tubers of either cultivar. Phosphorus increased significantly ($p < 0.05$) in Katahdin but not in Chippewa. Similar trends were observed for these two cultivars during each of the 2 years of the study. The cultivars, Sebago, Peconic, and Bake King also did not show any change in K and Mg; however, calcium was significantly decreased in PVX-infected tubers of these cultivars. Peconic also showed a significant ($p < 0.01$) increase in P content in PVX-infected tubers. A similar increase in P was shown in PVX-infected tomato fruit (Singh and Mall, 1973) and potato virus Y (PVY) infected potato sprouts (Panjar, 1960). However, in this study the cultivars differed in their response to P and Ca accumulation as a result of PVX infection. Katahdin and Chippewa did not show a significant change in Ca content over 2 years (Tables I and II), but Sebago, Peconic and Bake King showed a significant decrease in Ca content of

Table III. Micromineral Composition of PVX-Free (X−) and PVX-Infected (X+) Potatoes for Year 1[a]

variety, treatment	ppm dry wt Mn	Fe	Cu	B	Zn	Al	Cd
Katahdin, X−	23.3 ± 4.70	67.0 ± 1.00	16.0 ± 1.00	11.7 ± 0.35	23.0 ± 0.00	64.0 ± 6.00	
Katahdin, X+	18.8 ± 9.18	58.0 ± 0.00	9.0 ± 0.92	11.3 ± 1.70	37.0 ± 2.00	69.0 ± 17.0	
significance	NS	$p < 0.05$	$p < 0.05$	NS	$p < 0.05$	NS	
Chippewa, X−	38.0 ± 10.00	88.3 ± 1.75	16.5 ± 0.50	12.0 ± 1.00	13.5 ± 2.50	58.0 ± 6.00	
Chippewa, X+	38.0 ± 10.00	70.9 ± 1.10	9.5 ± 0.15	10.9 ± 2.10	30.5 ± 2.50	46.0 ± 0.00	
significance	NS	$p < 0.05$	$p < 0.05$	NS	$p < 0.05$	NS	

[a] All data are expressed as mean ± SE. NS represents not significant.

Table IV. Micromineral Composition of PVX-Free (X−) and PVX-Infected (X+) Potatoes for Year 2[a]

variety, treatment	ppm dry wt Mn	Fe	Cu	B	Zn	Al	Cd
Katahdin, X−	10.5 ± 2.50	53.2 ± 4.80	12.0 ± 1.00	7.1 ± 1.10	24.0 ± 1.00	51.6 ± 11.60	0.33
Katahdin, X+	5.5 ± 0.75	30.0 ± 5.00	6.8 ± 1.25	6.9 ± 0.14	56.7 ± 6.35	46.2 ± 1.85	0.50
significance	NS	$p < 0.10$	$p < 0.10$	NS	$p < 0.05$	NS	
Chippewa, X−	11.4 ± 2.20	58.3 ± 8.30	11.1 ± 0.35	8.2 ± 1.00	35.5 ± 2.50	66.7 ± 22.3	0.31
Chippewa, X+	7.7 ± 1.80	33.6 ± 0.40	6.4 ± 0.02	7.2 ± 0.84	52.5 ± 4.50	41.4 ± 1.45	0.28
significance	NS	$p < 0.10$	$p < 0.10$	NS	$p < 0.10$	NS	
Sebago, X−	11.1 ± 0.30	50.2 ± 0.20	13.4 ± 3.60	7.1 ± 1.10	15.5 ± 1.50	54.9 ± 9.15	0.24
Sebago, X+	9.1 ± 1.80	33.3 ± 0.75	10.6 ± 2.40	7.6 ± 0.70	22.1 ± 0.10	34.5 ± 5.50	0.32
significance	NS	$p < 0.01$	NS	NS	$p < 0.05$	NS	
Peconic, X−	10.7 ± 1.10	62.3 ± 3.75	11.7 ± 1.30	6.3 ± 0.59	15.5 ± 0.60	44.8 ± 3.60	0.22
Peconic, X+	10.7 ± 0.55	39.4 ± 1.60	8.7 ± 0.55	6.7 ± 0.41	31.9 ± 1.10	40.7 ± 1.60	0.27
significance	NS	$p < 0.05$	NS	NS	$p < 0.01$	NS	
Bake King, X−	12.8 ± 1.30	47.7 ± 2.40	14.9 ± 0.60	6.9 ± 0.92	22.9 ± 2.80	55.9 ± 4.05	0.19
Bake King, X+	9.9 ± 1.85	37.8 ± 0.20	8.9 ± 0.25	7.3 ± 1.34	37.5 ± 3.20	48.7 ± 2.75	0.34
significance	NS	$p < 0.10$	$p < 0.05$	NS	$p < 0.10$	NS	

[a] All data are expressed as mean ± SE. NS represents not significant.

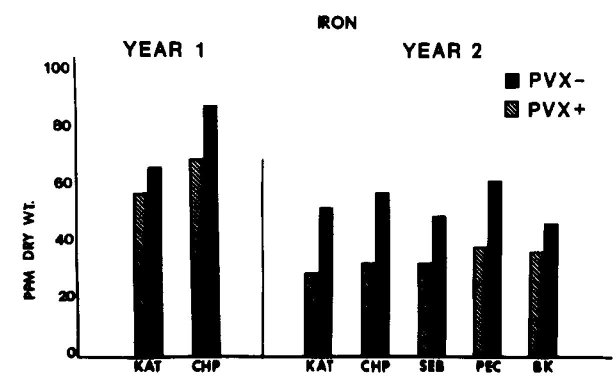

Figure 1. Effect of PVX infection on the iron content of potato tubers. KAT = Katahdin; CHP = Chippewa; SEB = Sebago; PEC = Peconic; BK = Bake King.

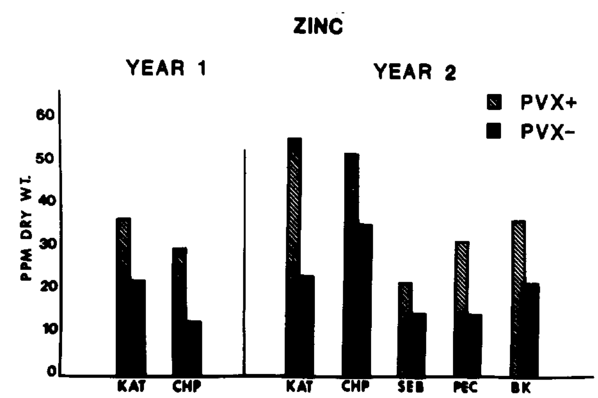

Figure 2. Effect of PVX infection on the zinc content of potato tubers. KAT = Katahdin; CHP = Chippewa; SEB = Sebago; PEC = Peconic; BK = Bake King.

PVX-infected tubers. Similar decreases in calcium content due to viruses in plant tissue have been reported (Wynd, 1943).

Microminerals. The content of microminerals is summarized in Tables III and IV. In all the cultivars the PVX-infected tubers had significantly lower levels of Fe (Tables III and IV; Figure 1). This is in agreement with Bergman and Boyle (1962), who reported significantly lower amounts of iron and copper in tomato leaves infected with tobacco mosaic virus. Copper was also significantly reduced in Katahdin, Chippewa, and Bake King cultivars, but no significant differences were observed in Sebago and Peconic varieties. In both years of the study and in all cultivars, the zinc content increased significantly in PVX-infected tubers (Figure 2). No significant differences were observed in the quantities of manganese, boron, and aluminum between PVX-infected and PVX-free tubers (Table IV).

PVX infection significantly altered the mineral composition of tubers, but the changes varied with the cultivar studied. Tubers of some cultivars with PVX had significantly less Ca, Fe, and Cu and significantly more P and Zn than those that were PVX free. An increase in cadmium was also observed, but since cadmium was included in only 1 year of the study, the data are not conclusive (Table IV).

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α-Chaconine and α-Solanine Content of Potato Products and Their Stability during Several Modes of Cooking

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Several commercial potato products were analyzed for their α-chaconine and α-solanine content by using high-performance liquid chromatography (HPLC). The α-chaconine content ranged from 0.04 to 97.9 mg/100 g of product while the quantity of α-solanine varied from 0.04 to 48.0 mg/100 g of product. Percent recoveries for α-chaconine ranged from 98 to 101% while those for α-solanine were 93–98%. Glycoalkaloid stability during four cooking procedures—frying, baking, microwaving, and boiling—was investigated, and it was determined that they were stable for all except frying where a slight loss of glycoalkaloids was shown. α-Chaconine and α-solanine were confirmed as the major glycoalkaloids in each product by thin-layer chromatography (TLC).

Potatoes contain glycoalkaloids, a class of naturally occurring toxicants, of which α-chaconine and α-solanine are the most prevalent in commercial tuber varieties. These two compounds are comprised of a steroidal-like alkaloid, solanidine, to which three monosaccharides are attached. α-Chaconine contains the sugars rhamnose (two moieties) and glucose, whereas α-solanine has the monosaccharides glucose, galactose, and rhamnose.

Several investigators have reported on the toxicological effects of the glycoalkaloids when consumed by humans. Poisoning and in a few cases death have occurred when potatoes with high total glycoalkaloid (TGA) content were consumed (Hanson, 1925; Willimott, 1933; Wilson, 1959). Teratogenic effects in various animal species have been described (Mun et al., 1975., Keeler et al., 1976; Allen et al., 1977). But epidemiological investigations attempting to correlate potato consumption and abnormalities in humans have produced conflicting results (Renwick, 1972; Emanuel and Sever, 1973). As a safety precaution though, a guideline of 20 mg of TGA/100 g of potatoes has been established as the maximum TGA content allowed in commercial tuber varieties.

Although 57% of all potatoes consumed in the United States today are in some processed form (Thornton and Sieczka, 1980), very little information has been collected on total glycoalkaloid content of processed potato products and none on individual glycoalkaloids to see if they are changed, decreased, or remain the same. Alvarado (1977) attempted to determine TGA values of some commercial products but had difficulty with the method employed. Sizer et al. (1980) and Maga (1980) investigated the TGA content of potato chips and potato flakes, respectively. Also, there is little information as to the stability of these compounds during various home cooking processes except for one report (Sizer et al., 1980) on TGA content during frying of potato chips.

This investigation was conducted to obtain the α-chaconine and α-solanine content of numerous commercial processed potato products and the effect of four cooking modes—boiling, baking, frying, and mircowaving—upon each glycoalkaloid.

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EXPERIMENTAL SECTION

Materials. Glycoalkaloids were obtained from potato blossoms by using the method of Bushway et al. (1980). These glycoalkaloids were separated into individual components for standards by HPLC (Bushway et al., 1979). Solvents used in extracting and partitioning were A.C.S. grade of the Fisher Scientific Co. (Pittsburgh, PA). HPLC-grade solvents (Fisher) were used for the HPLC analyses of glycoalkaloids and to dissolve the glycoalkaloid ammonium precipitate.

Processed potato products were purchased from several local stores, and several different brands of the same processed product were analyzed. Russet Burbank potatoes, which were used in the cooking studies, were obtained from the Aroostook State Farm, University of Maine, Presque Isle, ME.

Extraction, Cleanup, and Quantitation of Process Products. A 200–300-g sample (frozen commercial products were thawed first) was blended in a king-size Waring Blendor (3.8-L capacity) with 550 mL of methanol–chloroform (2:1) for 10 min at 18300 rpm, followed by vacuum filtration using a Buchner funnel fitted with Whatman No. 1 filter paper. The filtrate was brought to a final volume of 1 L. A 300-mL aliquot (a total of three

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