Chromium in Potatoes

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Chromium concentration in potatoes was determined, and tubers were labeled either intrinsically or extrinsically with radioactive chromate. A labeled chromium complex was isolated from preparations of raw, baked, or fried potatoes and chromatographed on gel permeation media. Potato pulp and peel contained 1.63 and 2.70 μg of Cr/g tissue, respectively. There was no correlation between the two, nor did they respond similarly to changes of variety or locations. No significant differences were apparent in relative migration of the isolated complexes except between raw and cooked extrinsically labeled preparations.

Little is known about the naturally occurring form of chromium in human foods and how this might compare with complexes isolated from others sources. One chromium-containing complex called the glucose tolerance factor (GTF) was isolated from Brewer's yeast (*Sacromyces carlesbergensis*) by Mertz (1969) and described as a positively charged molecule with a molecular weight of 400. A distinctly different complex, or group of complexes, was isolated by Blincoe (1974) and Starich (1981) from alfalfa and other higher plants and described as one more anionic complexes with a molecular weight of approximately 2900. Since absorption of minerals often depends on association with organic compounds, these differences may effect bioavailability. Studies by Blincoe and Starich (1983) suggested that intrinsic and extrinsic chromium labeling produced similar organic–chromium complexes in plant materials. Further differences in complex characteristics may result from use of standard food preparation methods.

The potato (*Solanum tuberosum*) is the fourth major source of carbohydrate for the population worldwide (Lopez de Romana et al., 1981). It has proved to be an excellent source of many nutrients (Vail et al., 1973), and preliminary data indicate it is relatively rich in chromium (Mertz, 1980). This vegetable is commonly prepared by a variety of standard food preparation methods.

This study has examined chromium concentration and the effect of standard food preparation methods on complex form as isolated from the potato. Intrinsic and extrinsic labeling methodologies were compared.

MATERIALS AND METHODS

Reagent Chemicals. All chemicals used were chemically pure, meeting the standards of the American Chemical Society where such standards have been published. Water used was distilled, deionized using a mixed-bed ion-exchange resin and stored in polyethylene containers. Radioactive ^{51}Cr (chromate) had a specific activity of 10–1000 Ci/g of Cr. The half-life was considered to be 27.71 days for all decay calculations.

Laboratory Ware. All glass, plastic, and porcelain ware were washed with laboratory detergent and rinsed with water, with 10% hydrochloric acid, and several times with distilled–deionized water prior to each use.

Atomic Absorption. Stable chromium was assayed by use of an atomic absorption spectrophotometer (Instrumentation Laboratories Model 251) with electrothermal atomizer (Model 455). Samples were prepared in 0.5% nitric acid and 25-μL aliquots hand-loaded into a pyrolytically coated carbon rod furnace. Samples were brought slowly (30 s) to a temperature of 75 °C and held for drying (30 s). Temperature was then raised to 1000 °C and held (30 s). Atomization was accomplished at 2200 °C and held for 5 s. Absorption was read at 357.9 nm. The detailed procedure and its validation have been published (Blincoe et al., 1987).

Measurement of Radioactivity. ^{51}Cr, a γ emitter, was measured in a well-type thallium-activated sodium iodine solid crystal counter equipped with single-channel analyzer and timer. Efficiency of ^{51}Cr measurement was 17%.

Gel Exclusion Chromatography. Sephadex G-25 was used for estimation of complex size (nominal column size 15 mm (i.d.) × 300 mm). The column was buffered at pH 7 with 0.01 M phosphate buffer and held at 4 °C. Aliquots of 0.5 mL were counted for radioactivity and then applied to the column (Blincoe and Starich, 1983). Twenty-drop (approximately 1 mL) fractions were collected and counted for radioactivity to determine peak location. Total radioactivity collected was compared to the initial amount present to verify recovery of all applied radioactivity. Void volume for the column was initially determined by blue dextran measured spectrophotometrically at 660 nm and verified for each run by the 285-nm absorption of protein in the unknown. The elution volume for ions was determined using ^{137}Cs and ^{51}Cr. The results are stated as relative migration (R_f), the ratio of the elution volume for the peak in question to the void elution volume.

Chromium Content of Potatoes. Four cultivars from four locations in Nevada and California representing the 1981, 1982, and 1983 crop years were analyzed. Pulp and peel were investigated separately. All samples were handled so as to minimize chromium contamination during sample preparation. Carbon-steel cutting instruments and equipment was used.

Potatoes were first washed in distilled–deionized water and then peeled. Adjacent cross-sectional slices of pulp were cut from the center of the potato, weighed, and dried in a microwave oven for 10 min at 20% power. Peelings were also weighed and dried. Pulp and peel were digested separately in concentrated nitric acid, and total chromium was determined by AAS (Blincoe et al., 1987).

Fifty potatoes were analyzed including samples of Russet Burbank, Pontiac Red, Norchip, and Kenebec cultivars. Potatoes were from Tule Lake and Edison in California and from Reno and Central Nevada. California potatoes were commercially grown, whereas the Nevada potatoes were from the University of Nevada Reno Experiment Station field laboratories. National Bureau of Standards Reference Material 1573 was carried through the entire procedure.

Radioactive Labeling of Potatoes. Intrinsic labeling was accomplished by injection of 1 mCi of ^{51}Cr into the

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Table I. Count Rate (cpm) for ^{51}Cr by Tissue Source

source	cpm/g
cortex	800
medulla	13
peeled potato	
slice 1	1005
slice 2	10
peel	
sample 1	238
sample 2	82

stem tissue of the growing plant. Tubers were harvested 3 days to 1 week postinjection. After rinsing and peeling, the juice was extracted on a Carver press operated at 1400 kg/cm^2 (cylinder diameter 4.5 cm) and then centrifuged at 10000g at 4 °C. Extrinsic labeling was accomplished by addition of 0.01 mCi of ^{51}C to the supernatant after extraction from unlabeled potatoes. Cooked potatoes were ground with mortar and pestle, and distilled water was added until an appropriate juice could be extracted. Size of the chromium complex was determined by gel exclusion chromatography. For comparison, ^{51}Cr and ^{137}Cs were also chromatographed.

Preparation Methods. Potatoes were prepared by standard cooking methods as described by Sutherland et al. (1973).

RESULTS AND DISCUSSION

The analytical procedure has been given elsewhere (Blincoe et al., 1987). It was similar to that of Verch et al. (1983). Good recovery (4.5 ± 0.7 μg/g) with NBS SR 1573 (certified value 4.5 ± 0.5 μg/g) was obtained. The standard deviation of analysis was ±0.25 ng/mL or ±3.5% of the average sample analyzed.

Fifty potatoes were analyzed for total chromium. Cross-sectional slices were taken from each tuber and adjacent slices paired for analysis. Data from these adjacent slices were not consistent. The standard deviation of such replications was 60–65% (±0.28 ppm). In an attempt to ascertain whether this variation was procedural or biological, intrinsically labeled tubers were examined. Cross-sectional slices were taken and medullary and cortical tissues separated (Thornton and Sieczka, 1980). Radioactive count rates demonstrated that the greater portion of the ^{51}Cr was located in the cortex of the tuber and was approximately 60 times that of medullary tissue (Table I). These higher count rates in the cortex would seem indicative of chromium deposition in cells of the cambium or in newly developing cells of the periderm. Erdman (1981) reported that radioactive carbon (from carbon dioxide) spread through tubers from the stem to bud end and that radioactivity was greatest in the periderm and did not necessarily spread into the pith. This is very similar to the results in Table I. Medullary tissue extends through the cortex to the eyes or buds of the tuber, resulting in a cortical layer of inconsistent thickness (Thornton and Sieczka, 1980). The higher chromium uptake of the cortex and the inconsistency of this layer explain variabilities in chromium concentration within one potato when adjacent slices (e.g., slices one and two in Table I) were analyzed.

Total chromium concentration was determined for four cultivars of potato from four growing locations. Pulp and peel were investigated separately, and results are reported on a dry-weight basis. Statistical analysis of duplicate data shows the standard deviation of analysis to be ±0.05 ppm. The chromium content of potato pulp was between 1.0 and 2.0 (mean 1.63) ppm (mg/kg). Content of peel was between 2.4 and 4.7 (mean = 2.70) ppm. The difference between the two tissues was significant at the 1% level; however, there was no correlation between concentrations (r = 0.169).

Table II. Three-Way Analysis of Variance of the Chromium Content of Potatoes

variation	mean square	F
between pulp and peel (A)	17.38	23.94[b]
between two locations (B)	0.02	0.04
between two varieties (C)	1.71	3.33
A by B	4.90	9.59[b]
A by C	3.96	7.74[a]
B by C	1.10	2.16
three-way interaction	0.43	0.84
replication	1.51	2.94
error	0.51	

[a] $p < 0.05$. [b] $p < 0.01$.

Table III. Mean Chromium Content of Potato by Location and Variety

source	N	Cr, μg/g dry weight: pulp	peel
location			
central Nevada	12	1.05	3.66
Reno, NV	6	1.90	2.70
variety			
Russett Burbank	15	1.34	3.85
Pontiac Red	6	1.61	2.50

Table IV. Chromium Content of Potatoes by Investigator

investigator	Cr, μg/g (dry wt)
current work	1.0–2.0
Farre and Lagarda (1986a,b)	0.11[b]
Gough et al. (1986)	0.60[b]
Harris et al. (1981)	0.91–1.45
Kirkpatric and Coffin (1974, 1977)	0.18–0.52[b]
Meringer and Smith (1972)	0.56–1.36[b]
Mondy et al. (1986)	1.08
Shacklette (1980)	0.021
Shripchenko (1972)[a]	tr–1.80
Smart and Sherlock (1985)	0.60[b]
Varo et al. (1980)	0.008–0.12[b]

[a] As reported by Smith (1977). [b] Reported on fresh weight basis, converted herein to dry weight as 25% of wet weight. [c] Extracted with ethanol or HCl.

A three-way analysis of variance of a subset of these data (Table II) suggests that both location and variety had a statistically significant effect on chromium concentration ($p < 0.01$ and $p < 0.05$, respectively). The interaction of the pulp–peel difference with location and variety was significant. There was no replication effect. An examination of the means demonstrated that pulp and peel did not respond in a like manner to changes in variety or location (Table III).

These results are comparable to those of other investigations (Table IV). Reported values are quite divergent. A wide variety of analytical methodology is represented. All data were converted to a dry basis. Differences may be due, in part, to specific cultivars analyzed, location factors, soil, handling effects, or the analysis of pulp and peel separately. At least one of the groups (Harris et al., 1981) analyzed the whole ground potato. That group found no significant varietal differences in chromium concentration and demonstrated that mineral content of the tuber was independent of soil concentration and concentration in the rest of the plant. However, Smith (1968) pointed out that mineral concentration of the potato tuber varied with cultivar, cultural practice, maturity, storage, and area of growth.

Table V. Relative Migration of Chromium Complex on Sephadex G-25

source	extrinsic label R_f[a]	no.	intrinsic label R_f[a]	no.
raw	1.64 ± 0.08	11	1.56 ± 0.13	5
baked	1.52 ± 0.10	6	1.45	1
fried	1.48 ± 0.02	3	1.59 ± 0.09	3
boiled	1.40 ± 0.05	3	1.67[b]	
cesium chromate	1.94 ± 0.13	3		

[a] R_f = elution volume of ^{51}Cr peak/elution volume of blue dextran. [b] Chromium in the cooking water. Preparation of boiled intrinsic labeled potatoes resulted in loss of label in the cooking water.

Relative migration (R_f) of the chromium complex was determined on Sephadex G-25 for both intrinsically and extrinsically labeled potato extract. This technique provides a crude estimate of molecular weight. It does not, however, give any indication of complex charge and is readily influenced by molecular configuration. On Sephadex G-25, proteins elute with the void volume. In contrast, cesium and inorganic chromium ions migrate with R_f 1.94 ± 0.13.

Although some differences in migration were apparent, mean R_f values for all potato samples was 1.52 ± 0.08 (Table V). Relative migration of the complex from intrinsically labeled raw potatoes showed the greatest variability. Half of these potatoes were young, small developing tubers, whereas the remainder were mature tubers from which shoots had started. Relative migration values of the chromium complex from these two subgroups were 1.84 and 1.50, respectively. A single extract from one young tuber yielded an R_f of 1.93 immediately after extraction and an R_f of 1.50 several hours later. The *in vitro* formation of a higher molecular weight complex from a lower molecular weight precursor was reported in alfalfa (Blincoe and Starich, 1983).

A *t*-test showed no significant differences in migration of chromium from intrinsically and extrinsically labeled potatoes (Table V). All ^{51}Cr from intrinsically labeled potatoes migrated in one band. Extrinsic labeling also resulted in labeling of high molecular weight material (probably protein) that migrate in the void volume of the columns. Previously no difference had been found between chromium complexes from intrinsically and extrinsically labeled alfalfa and wheatgrass (Blincoe, 1974; Blincoe and Starich, 1983). It had been shown that the ^{51}Cr in intrinsically or extrinsically labeled alfalfa migrated with the same R_f as stable chromium from unlabeled alfalfa (Starich and Blincoe, 1983). Relative migration of the chromium complex from extrinsically labeled raw potato extract was similar to that isolated by Blincoe (1974) from alfalfa and by Starich (1981) from alfalfa, crested wheatgrass, hays, and apples (Table VI).

Comparison of the relative migration of radioactive chromium from of all raw and cooked potatoes indicated a significant difference ($p < 0.05$) between raw and boiled potatoes (Table V). The difference between extrinsically labeled raw and baked ($p < 0.05$) or fried ($p < 0.01$) potatoes was also significant. The chromium complex was extracted into the cooking water by boiling. The decrease of R_f during cooking would indicate a larger complex is formed during cooking. This larger complex is about the same R_f as extracted from (uncooked) Brewer's yeast by the same techniques (Blincoe et al., 1983).

Human dietary intake of chromium has been reported at 24–47 μg/day (Bunker et al., 1984; Kozlovsky et al., 1984; Offenbacher et al., 1984). The potato apparently offers appreciable amounts to the diet with a 100 g (fresh weight) of tuber conceivably providing 163 μg or 81–326% of the safe and adequate allowance recommended by the National Academy of Sciences (1980). Food processing has been suspected of removing a large quantity of the chromium naturally occurring in foods (Toepfer et al., 1977). The mineral was, however, lost from potato pulp tissue only during boiling. Differences between relative migration of cooked and raw preparations suggest changes in size and/or configuration of the organic–chromium complex. These changes may affect availability of the mineral and therefore dietary efficiency of potatoes as a source of chromium.

Table VI. Relative Migration (R_f) of the Chromium Complex by Investigator

investigator	extract source	R_f[a]
current work	water from boiling intrinsically labeled potato	1.67
	raw potato: extrinsically labeled	1.64
	raw potato: intrinsically labeled	1.56
	all cooked potatoes	1.48
Blincoe (1974), Starich (1981)	alfalfa: extrinsic and intrinsic label	1.61
Blincoe et al. (1983)	brewer's yeast	1.45–1.55

[a] Relative migration on Sephadex G-25.

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Chromium Supplementation of Turkeys: Effects on Tissue Chromium

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Four groups of 33-week-old turkey hens were fed either the basal diet for laying hens or the basal diet supplemented with 25, 100, or 200 μg of chromium as chromium chloride/g of diet. Liver Cr concentrations of the turkeys sacrificed after 5 weeks were 1.9, 36, 168, and 326 ng/g (wet weight). Similar trends, but higher chromium values, were observed for kidney samples. The chromium concentrations of the dark and white meat, eggs, and other edible tissues were not increased sufficiently for these tissues to serve as sources for Cr-enriched foods. Therefore, turkey liver is suitable for Cr enrichment studies while the eggs, dark and white meat, and other edible parts do not appear to be enriched sufficiently for these tissues to be used as sources of experimental high-Cr foods.

The absorption of dietary chromium (Cr) in humans eating freely chosen diets is inversely related to Cr content of the diet (Anderson and Kozlovsky, 1985). As a result of this inverse relationship of Cr absorption and dietary intake, the urinary excretion of Cr at intakes below 40 μg/day is relatively constant. At daily Cr intakes above 40 μg, absorption appears constant at approximately 0.4% and urinary losses increase with increasing intake (Anderson et al., 1983). However, daily Cr intakes in excess of 50 μg, do not usually occur unless subjects are taking supplements containing Cr.

To identify Cr-rich foods both suitable for human consumption and providing potential Cr intakes in excess of 50 μg/day, turkeys were supplemented with varying amounts of Cr. Turkeys were chosen for their size and suitability of the various edible parts as sources of food for human consumption. Turkeys could also be labeled with stable isotopes of Cr, and use of these labeled parts as enriched food sources will greatly facilitate Cr absorption studies in humans.

MATERIALS AND METHODS

Large white breeder hens, 33 weeks of age, were housed individually in suspended galvanized cages. The temperature of the room was maintained at 21 ± 1 °C, humidity 70 ± 5, with 14-h light and 10-h dark cycle. Turkeys were fed ad libitum a corn–soybean meal based diet containing 17% crude protein (Rosebrough and Steele, 1985) (Cr concentration 506 ± 59 ng/g) and this diet supplemented with 25, 100, and 200 μg of Cr as chromic chloride/g of diet. Two turkeys in each group were sacrificed after 1 and 5 weeks. Turkeys were sacrificed by cervical dislocation and the turkey parts removed with use of chromium-free plastic gloves; parts were rinsed with

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