DISTRIBUTION OF COMPONENTS IN SUGARBEET ROOT

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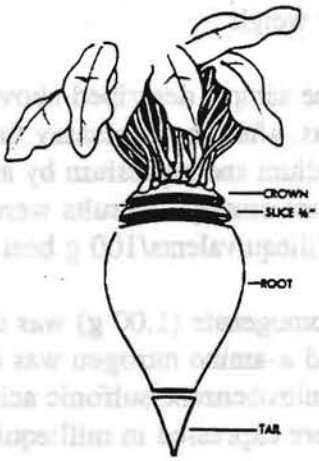
I. INTRODUCTION

Amalgamated Sugar has for many years furnished sugarbeet growers with data on the relative levels of sugar and non-sugars in various portions of a typical sugarbeet. This data, based on an earlier study is given in the figure shown below, from the Amalgamated Sugar Company Grower's Guidebook.



Beet Section	Wt. % of Total	Purity	Sucrose %	Invert % Total	K, % Total	Na, % Total	Nutrient Index % of Total
Crown	12.5	65.7	7.0	53.1	19	34	25
Slice	11.5	88.2	14.3	6.5	9	9	16
Root	69.2	89.1	15.4	34.9	64	52	54
Tail	6.8	83.5	13.5	5.5	8	5	5

K—Potassium, Na—Sodium, N—Nitrogen

In 1990 it was decided to verify this data in a currently grown sugarbeet variety. In addition, analytical data not included in the original study was obtained.

II. RESULTS AND DISCUSSION

One hundred freshly dug sugarbeets from a single field were transferred to the Research Laboratory where they were washed. Beets were then cut into three sections, a crown, slice, and root. Generally the cut between "slice" and root was made so that most or all leaf scars were excluded from the root. A "slice" of 1/4" to 3/8" in thickness was taken and all remaining upper material became the crown sample. The weight of each of the three sections was recorded and the root samples were then quartered lengthwise and three quarters were discarded. Crown, slice, and the one-quarter root sample, were then placed in polyethylene zip-lock bags for freezing. Samples were labelled in a way such that the root, slice, and crown for a particular sugarbeet could be identified.

For analysis, samples were thawed, cut into cubes with a knife, and chopped with a Hobart chopper. Chopped beet tissue was then used to prepare a 60:40 homogenate by weighing 60.00 g beet, 40.00 g water and blending for five minutes. Crown and slice tissue was somewhat dryer and a 50:50 homogenate was prepared. Homogenate was either analyzed directly or used to prepare juice using an Acme juicer.

Analysis for individual constituents was carried out as outlined below.

(1) Invert — 2.5 g of homogenate was diluted to 50 ml with deionized water (mixed bed ion exchange treated). This sample was used for both invert and cation determinations. Invert was determined by the hexokinase/glucose-6-phosphate dehydrogenase enzymatic method. Results were expressed as percent by weight.

(2) Cations — The sample described above for invert determination was, after any necessary further dilutions, analyzed for sodium and potassium by atomic absorbtion (AA) spectrometry. Results were calculated as milliequivalents/100 g beet tissue.

(3) Amino Nitrogen — Homogenate (1.00 g) was diluted to 100 ml with water and α-amino nitrogen was determined by a trinitrobenzene sulfonic acid (TNBS) method. Results were expressed in milliequivalents nitrogen/100 g beet.

(4) Conductivity — Conductivity was measured directly on juicer juice using a platinum cell.

(5) Sucrose — Approximately 1.1 g of homogenate was weighed to the nearest 0.0001 g and treated with 10.00 ml of internal standard solution containing 0.15 g salicin/10 ml. After silylation with trimethylsilylimidazole, sucrose was determined by gas chromatography (GC).

(6) Raffinose — Samples of juicer juice were diluted by a factor of three with water and analyzed by the raffinose enzymatic method (Boehringer). Only eighteen of the one hundred samples were analyzed for raffinose. Results (ppm/solution) were expressed as an approximate value for ppm/beet by:

$$\text{ppm} \times \frac{100\text{ g homog}}{60\text{ g beet (or 50 g where applicable)}} \times 3$$

Note that this calculation neglects density changes on dilution.

(7) Synthetic Thin Juice Purity — Synthetic thin juice purity was determined directly on juicer juice.

Values for thin juice non-sugars (%/beet), calculated from synthetic thin juice purity and sample sugar content, were used with root, slice, or crown weights to calculate weight of thin juice non-sugars per portion.

(8) Anions — Juicer juice was diluted to give anion levels in the 0-50 ppm range, filtered through a membrane filter, and injected on an anion exchange column in the Dionex ion chromatograph. Results were calculated in g/100 RDS using the juicer juice solids levels and converted to milliequivalents/100 g beet using average purity values.

Analytical data was entered in a spreadsheet program and converted to the desired units. Mean levels of each constituent in crown, slice, and root were then calculated for comparison but for the main goal of the study, the determination of distribution of constituents between the three beet fractions, the constituent levels in each sample, not mean values, were used. The level of a constituent in each fraction was multiplied by the weight of that beet portion to determine the quantity of constituent in the fraction. This quantity was then divided by the total quantity of constituent in that particular sugarbeet to give the ratio of constituent in the sample to total in the beet. For example, as shown in Table 1, one sample consisted of three fractions with betaine levels shown in the second data column from the right. Total betaine weight was calculated from

TABLE 1
Example of Distribution Calculation

	Fraction Wt.(g)	Betaine (%)	Betaine Wt. (g)	Betaine (% of total)
Crown	63.83	0.58	0.370	9.59
Slice	77.29	0.40	0.309	8.01
Root	1381.00	0.23	3.18	82.38
		Total Betaine	3.86	

weights for fractions as shown in the third data column. These values were then divided by the total betaine weight for the beet (3.86 g) and converted to the percentages of total betaine shown in the right hand column. Finally, mean percentages for all roots, slices, and crowns were calculated from the data set of individual percentages.

For various reasons, including insufficient sample size and time limitation, not all samples were analyzed for every constituent. Data were not used for distribution calculations unless all three portions of the same beet were analyzed. Sample numbers used for various constituents are given in Table 2.

TABLE 2
Number of Samples

Component	Number of complete samples used for distribution calculations
Sucrose	83
Invert	83
α-Amino nitrogen	96
Cations	95
Anions	47
Betaine	84
Extractable sugar	38
Thin juice non-sugars	38
Raffinose	18

The bar graphs shown in Figure 1 on the next two pages give mean constituent levels for the three beet fractions in the usual units. Note that crowns averaged low in sugar content (10.88%) and synthetic thin juice purity (77.17) relative to root samples (17.84% sucrose, 92.93 purity). Almost all non-sugar constituents are present at higher levels in crown tissue than in root tissue, as would be expected, with slice tissue in between. There are, however, several interesting variations in non-sugar levels in root relative to crown. On the first page of bar graphs notice that α-amino nitrogen and sodium levels in the crown average 3.6 to 3.7 times as high as levels in the root but potassium in crown tissue is only present at 1.8 times the level in root tissue. Clearly sodium and α-amino nitrogen compounds show a greater tendency to be concentrated in the crown and are thus more important with respect to proper beet topping. On the other hand potassium levels in the root are significantly higher in ratio to crown potassium, i.e. potassium is a more important non-sugar in the root than sodium or amino nitrogen. This fits the general perception that high potassium levels are somehow "worse" than high sodium levels and suggests that this is due partly to the fact that sodium is more easily removed by topping.

The bar graphs also show anion content and here differences in relative levels are even more extreme. The strongly ionized inorganic anions, chloride, sulfate, and nitrate, are much more significant in crowns with levels of 4 to 5.8 times as high as the root. Phosphate, however, like potassium, shows a crown level of only 1.8 times as high as the root level. The organic anions, malate and oxalate, are even more significant constituents in sugarbeet root. Oxalate is

the only non-sugar measured that is present at a higher level in root tissue than in crown or slice tissue and, as shown in the graph, is present at nearly twice the level of crown tissue.

Graphs are also shown for conductivity, invert, and raffinose which are all significantly higher in crown tissue.

Levels for total cations and total anions are given in the last graph. For all three sugarbeet fractions the measured anions (chloride, sulfate, nitrate, phosphate, malate, and oxalate) account for 60-65% of the total anion level that must be present to balance measured total cations. Remaining anion balance would be distributed among unmeasured anions (such as other organic acids) and anionic forms of measured constituents (such as some amino acids).

The second series of bar graphs (Figure 2) gives the mean value for the percentage of each component in root, slice, and crown tissue. As discussed above, these values take into account the weight of each beet section and values are given as a percent of total component for the beet. Due to the much higher weight of root samples than crown or slice, over 50% of any component is present in the root. Differences in distribution between crown, slice, and root, however, are very dramatic and easier to visualize than in the previous series of graphs showing only mean levels. Note that 91.75% of measured sucrose is present in the root with the remainder fairly evenly divided between crown and slice. The distribution of thin juice non-sugars, derived from synthetic thin juice purities, is especially important because unlike all non-sugars measured in beet tissue these are the components that carry through juice purification and end up in thin juice and molasses. As shown in the graph, sugarbeet crowns contain an average of 14.7% of total thin juice non-sugars compared with only 4.04% of total sugar.

Data for specific non-sugars shows root tissue contains only 68.78% of total α-amino nitrogen and 76.57% of total betaine. The potassium and sodium values are again quite different with much of the total sodium (30.07%) in the crown and slice which together make up only 11.8% of the total weight. Of the total potassium only 17.37% is in the crown and slice. This again emphasizes the importance of potassium levels in the root samples.

Values for anion distribution show even more pronounced differences. Crown and slice tissue together contain: (1) 40.0% of total chloride; (2) 38.04% of total nitrate; and (3) 32.23% of total sulfate. Phosphate distribution seems to resemble potassium distribution with only 18.5% in the crown and slice and 81.5% in the root. Finally the two organic anions, as would be expected from concentration values, are heavily concentrated in the root. In fact, 92.51% of total oxalate is in the root, slightly higher than the fraction of total sucrose in the root. A lower fraction, 86.87%, of total malate is present in the root. The last page of bar graphs shows that significant percentages of invert and raffinose are present in beet crowns.

Acknowledgements

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FIGURE 1

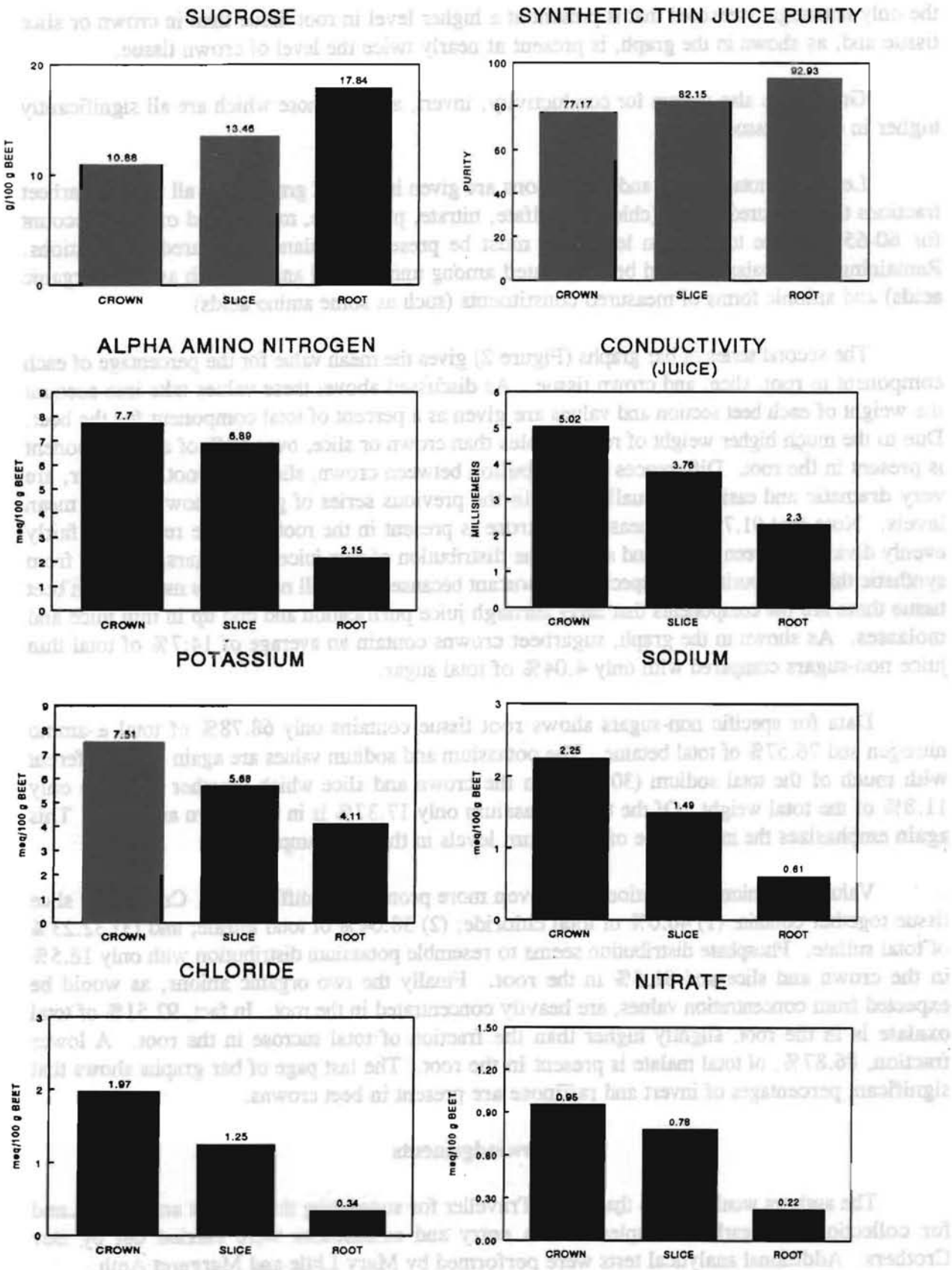
SUCROSE
g/100 g BEET
10.88
13.46
17.84
CROWN
SLICE
ROOT
SYNTHETIC THIN JUICE PURITY
PURITY
77.17
82.15
92.93
CROWN
SLICE
ROOT
ALPHA AMINO NITROGEN
meq/100 g BEET
7.7
6.89
2.15
CROWN
SLICE
ROOT
CONDUCTIVITY
(JUICE)
MILLISIEMENS
5.02
3.76
2.3
CROWN
SLICE
ROOT
POTASSIUM
meq/100 g BEET
7.51
5.68
4.11
CROWN
SLICE
ROOT
SODIUM
meq/100 g BEET
2.25
1.49
0.61
CROWN
SLICE
ROOT
CHLORIDE
meq/100 g BEET
1.97
1.25
0.34
CROWN
SLICE
ROOT
NITRATE
meq/100 g BEET
0.95
0.78
0.22
CROWN
SLICE
ROOT

FIGURE 1
(continued)

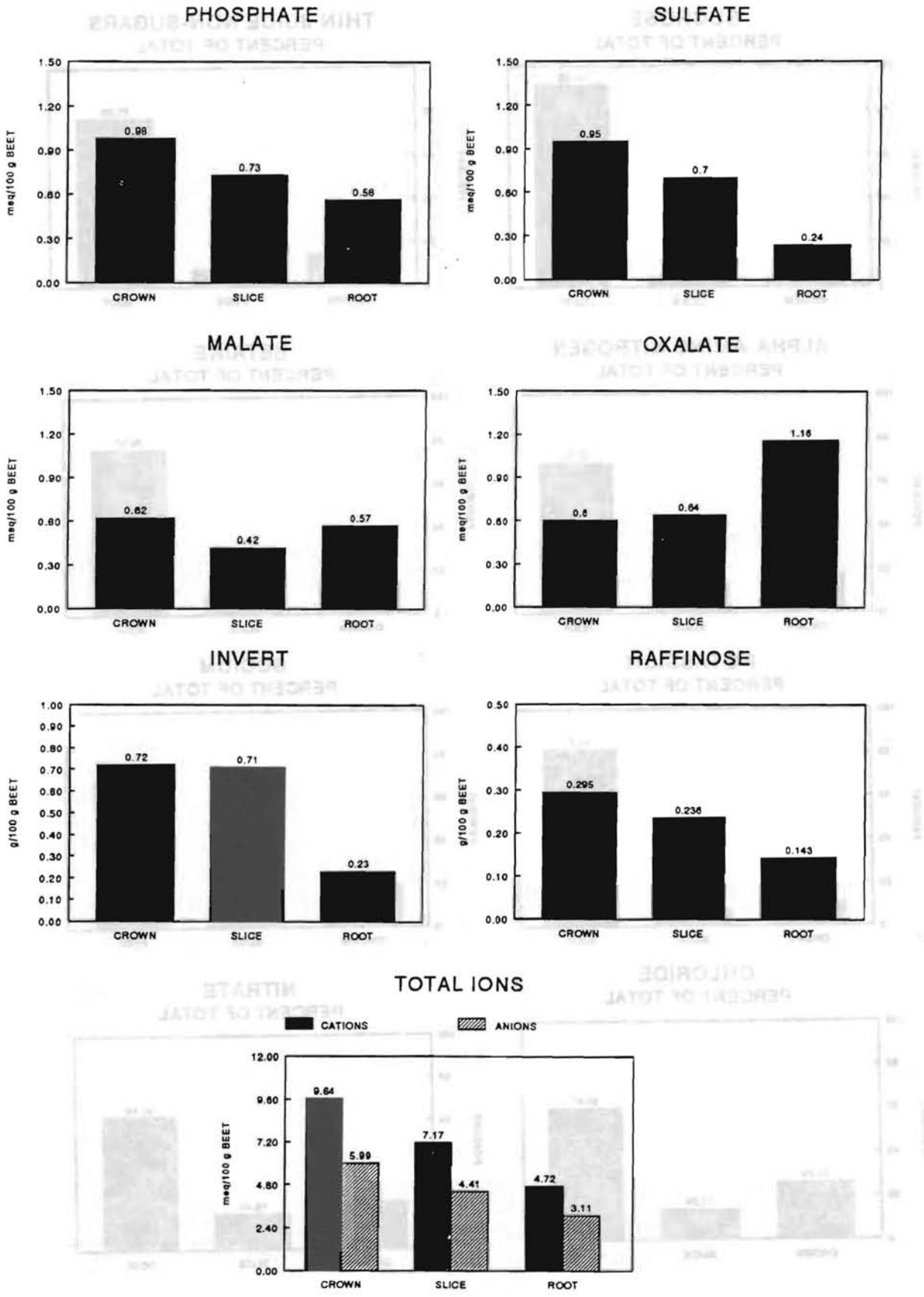

FIGURE 2

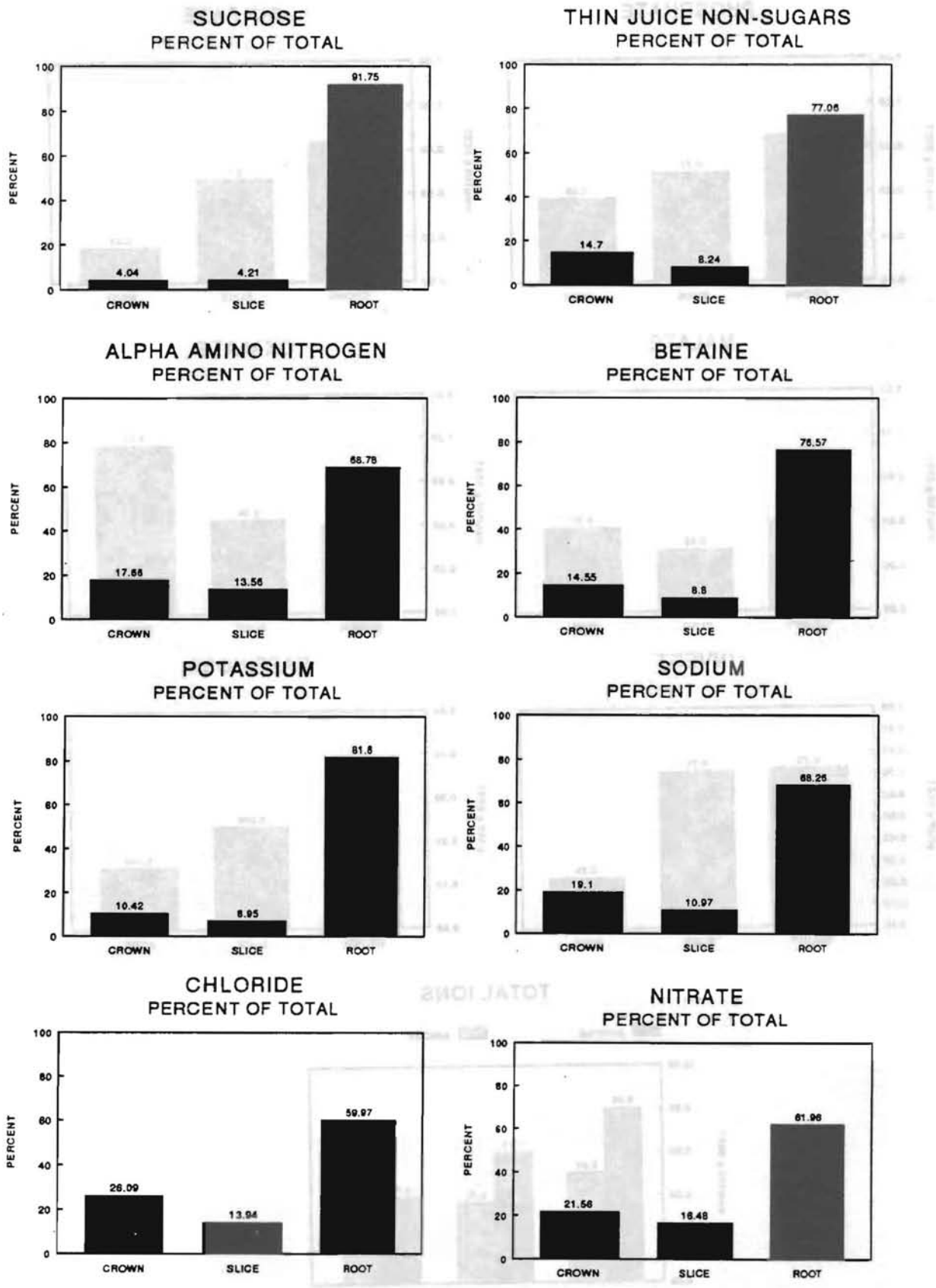
SUCROSE
PERCENT OF TOTAL
PERCENT
4.04
4.21
91.75
CROWN
SLICE
ROOT
THIN JUICE NON-SUGARS
PERCENT OF TOTAL
PERCENT
14.7
8.24
77.06
CROWN
SLICE
ROOT
ALPHA AMINO NITROGEN
PERCENT OF TOTAL
PERCENT
17.66
13.56
68.78
CROWN
SLICE
ROOT
BETAINE
PERCENT OF TOTAL
PERCENT
14.55
8.8
76.57
CROWN
SLICE
ROOT
POTASSIUM
PERCENT OF TOTAL
PERCENT
10.42
8.95
81.6
CROWN
SLICE
ROOT
SODIUM
PERCENT OF TOTAL
PERCENT
19.1
10.97
68.26
CROWN
SLICE
ROOT
CHLORIDE
PERCENT OF TOTAL
PERCENT
26.09
13.94
59.97
CROWN
SLICE
ROOT
NITRATE
PERCENT OF TOTAL
PERCENT
21.56
16.48
61.96
CROWN
SLICE
ROOT

FIGURE 2
(continued)