EFFECT OF CROWNING ON SUGAR BEET STORAGE

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I. Introduction

During the 2002-03 crop year, an extensive study of the storage characteristics of sugar beets was planned and carried out to resolve questions on the quality of beets, treated by various crowning methods, after normal storage in the Amalgamated Sugar Co. growing region. The study was designed to compare beets with: (1) only tops removed; (2)a full crowning to the lowest leaf scar (approximately 4% beet weight removal); and (3)a minimal crowning leaving a one to two inch diameter cut surface ("dollar-sized" crown). Replicate captive samples were stored at three different storage locations: an unventilated pile; a ventilated outside pile; and inside storage.

II. Experimental Methods

Captive samples were prepared from sugar beets grown in the Twin Falls, Idaho area, using beets, dug from six adjacent rows, with only the tops removed. Beets were selected to be as uniform as possible in size (in the 3 - 4 lb weight range with weights checked using a household scale) and beets were then scraped free of most soil and lightly brushed with a wire brush. Each sample consisted of seven beets and samples were bagged using tare bags for control samples to be analyzed immediately and polymer mesh volleyball bags for captive samples to be stored in beet piles. Each sample was weighed to the nearest 0.1 lb using a platform electronic balance and reweighed after any crowning treatment. All crowning treatments were carried out using a standard taring machine from a tare laboratory. Treatments used in the test were:

1) Uncrowned, tops removed at harvest.

2) Full crown to the lowest leaf scar.

3) One to two inch diameter or "dollar-sized" crown.

Ten replicate samples of each treatment were prepared for each of the following locations:

1) Control samples for immediate laboratory analysis without storage.

2) Unventilated storage within a normal factory pile.

3) Ventilated, outdoor storage in a beet pile containing regularly-spaced air ducts for lowering storage temperatures (without freezing).

4) Storage Building. Indoor storage with air ducts under the floor allowing cool outside air to flow through the pile.

Samples for immediate laboratory analysis were transported to Amalgamated Research (ARi) and stored at cold room temperature (35° F. or 5° C.) for several days until they could be chopped and frozen for further analysis. Captive samples were transported to storage locations and suspended from ropes in the beet pile during normal building of the pile. In general, each storage site in the pile contained one replicate of each crowning treatment. In late February or early March of 2003, as piled beets were reloaded for processing, samples were retrieved and transported to ARi. Samples were stored briefly (less than one week) in the cold room until chopped and frozen. Storage time was taken as the period between sample preparation (on Oct. 28, 2002) and the day the sample was chopped, including the few days of cold room storage.

Before analysis, stored beet samples were weighed (in the bag) to allow calculation of sugar losses based on original beet weight. The number of beets with visible regrowth and significant mold was also recorded. Beets in each sample were then washed thoroughly to remove adhering soil. For analysis, each beet was sliced longitudinally and one eighth sections of all beets in a sample were composited to give material representing the sample. Composite samples were then sliced further to give pieces small enough to run through a Hobart cossette chopper. The composite chopped beet samples were then frozen for further analysis when time permitted.

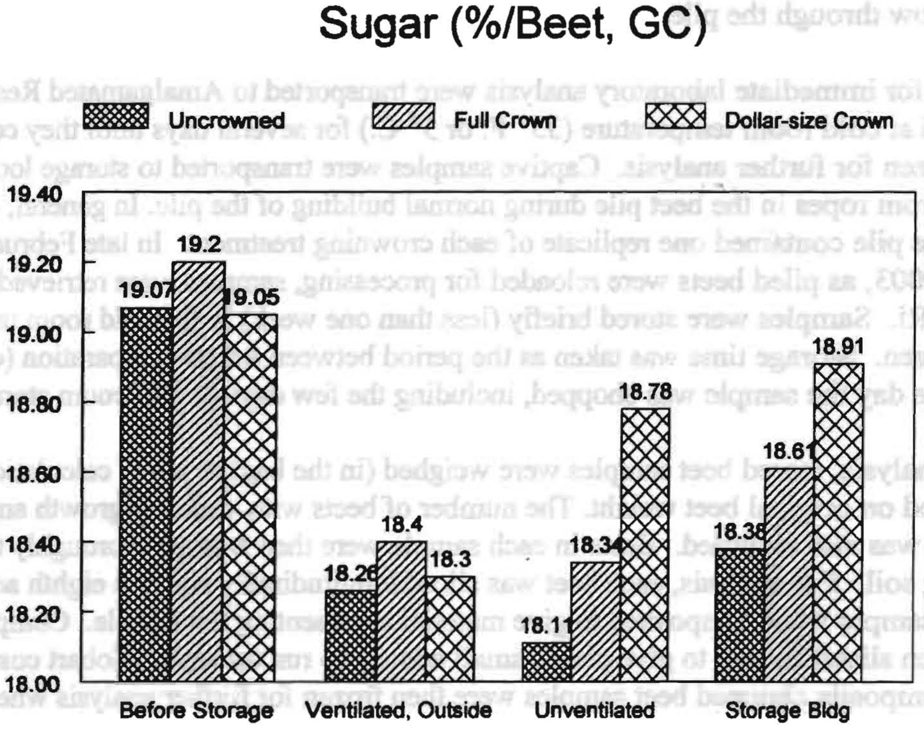
For analysis, chopped beet samples were thawed, mixed, and polarimetric sucrose was measured by the standard hot digestion method. Chopped sample was also used directly for moisture determination by oven drying. A 60/40 homogenate (60 g beet/40 g water) was prepared, by blending, for other analytical determinations including: gas chromatographic sucrose level; invert by the hexokinase enzymatic method; and raffinose by the Boehringer enzymatic method. From the 60/40 homogenate, juice was expressed using a centrifugal juicer and used for determinations of direct juice purity and synthetic thin juice purity by the standard methods.

III. Results and Discussion.

A. Beet composition before and after storage.

The following graph (Figure 1) gives mean values for sugar content by gas chromatography. As expected, the control beets show a slightly higher sugar content after full crown removal, as is true with the beets from the outside ventilated pile, but the beets stored in unventilated or indoor storage show the highest sugar content for dollar-sized crowned samples. Due to variation between replicates within a treatment, the differences between a full crown or dollar-sized crown and uncrowned beets are not significant at the 95% confidence level, according to a t-test comparison.

Figure 1

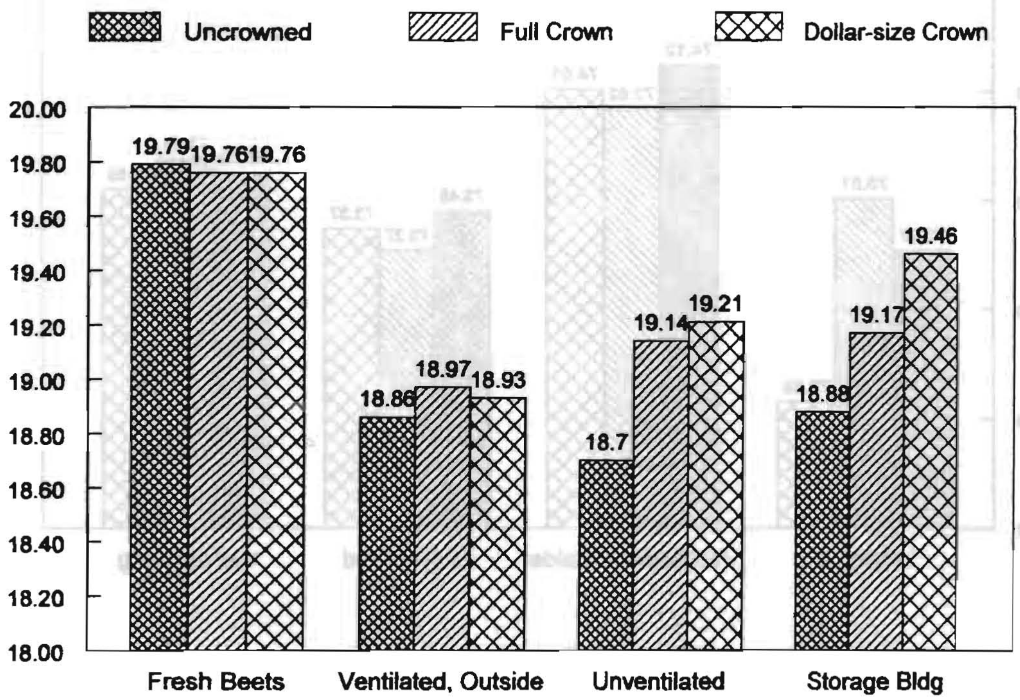


Values of t for dollar-sized crown versus uncrowned differences for storage building and unventilated samples are the highest at 2.06 and 1.99 respectively, with a critical t of 2.10. Another way of looking at the data however, is to compare mean values for stored beets with those of respective treatments of unstored control samples. Means for uncrowned and full crowned beets stored unventilated or in a storage building are significantly lower than those for unstored beets but means for dollar-sized crowns at unventilated and storage building locations are <u>not</u> significantly different than those for unstored beets.

Comparisons of polarimetric sucrose by hot digestion look similar to those for GC sucrose. Again the sugar content values for dollar-sized crowned beets are higher than other treatments in unventilated and storage building locations. For storage building data only, the difference between dollar-sized and uncrowned beets is statistically significant at the 95% level. In the case of polarimetric sugar content, t tests show values for uncrowned and fully crowned beets to be significantly lower than unstored samples for all three storage locations but dollar-sized crowned beets stored in unventilated and storage building piles are <u>not</u> significantly lower than unstored beets.

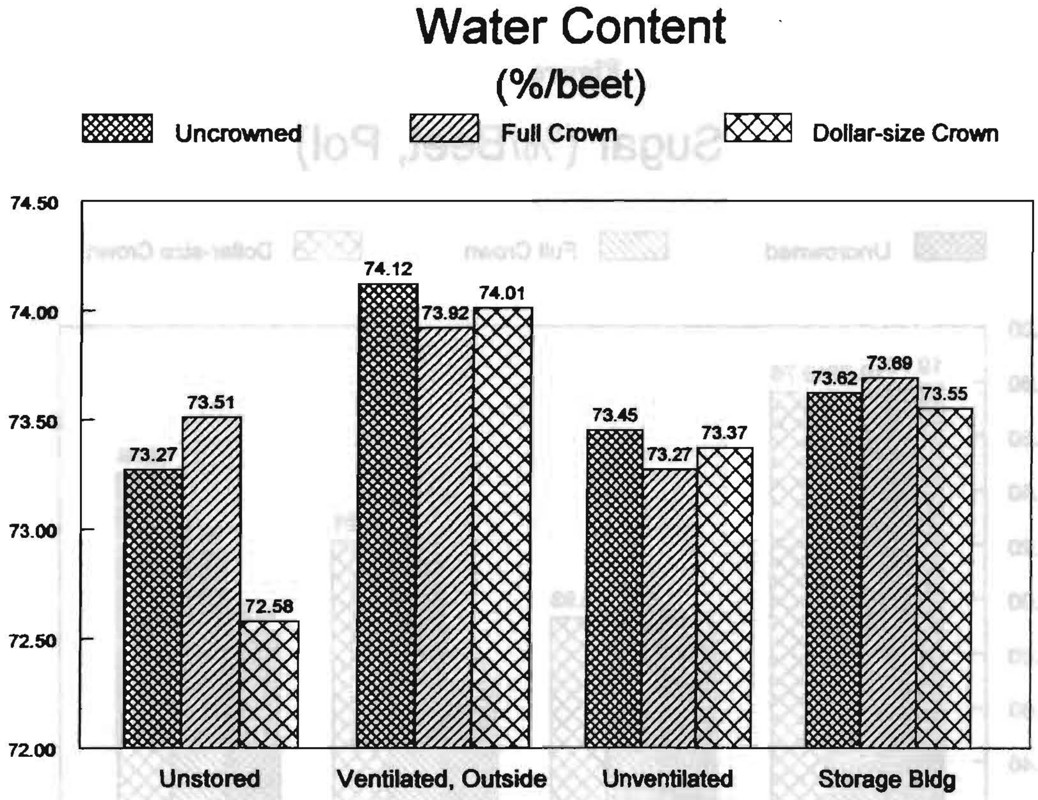
Figure 2

Sugar (%/Beet, Pol)



To detect any possible effects of dehydration on sugar content, oven dry moisture loss values were determined for all beet samples. Mean values of oven dry moisture content for each treatment are shown in Figure 3. Note that beets stored in the ventilated outdoor pile retained more moisture than the other storage locations and even than the control samples processed immediately at ARi without storage. This undoubtedly contributes to the lower sugar content values for these samples evident in the GC and pol value graphs shown above.

Figure 3



The similar trends, with crown treatment, obtained whether or not dehydration is taken into account are demonstrated in the following graph (Figure 4) which shows values for gas chromatographic sucrose content based on dry substance in beet. The unusually low moisture content (high solids content) obtained for dollar-sized crowned unstored beets resulted in a significantly lower sugar content based on dry solids. Otherwise, the pattern of relative levels looks somewhat like that obtained with GC sucrose based on beet weight. Note, however, that the correction for moisture content reveals the somewhat better storage conditions in the ventilated outside pile; sucrose levels based on solids are much closer to those for unstored beets than they appear to be from the sucrose/weight values shown in Fig. 1. In fact, for the ventilated outside storage samples, the uncrowned and dollar-sized crown samples are not significantly different than the comparable unstored beets. Both unventilated and storage building dollar-sized crowned samples show higher mean values for sucrose/dry solids than for the corresponding uncrowned samples, although only the difference for storage building samples is statistically significant at the 95% level. In this case also, both unventilated and storage building uncrowned and full crowning treatments are significantly lower in sucrose/dry solids than unstored beets but dollar-sized crowned samples are <u>not</u> significantly lower than unstored beets.

Figure 4

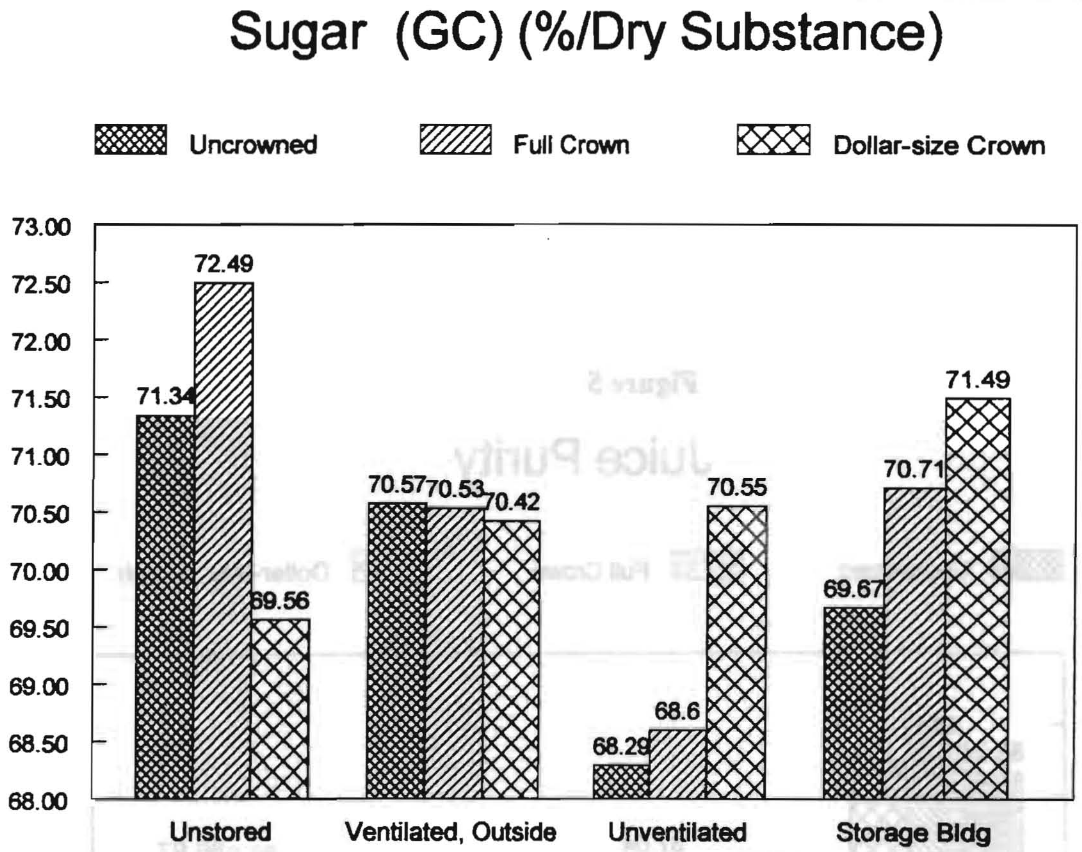

Sugar (GC) (%/Dry Substance)
Uncrowned
Full Crown
Dollar-size Crown
73.00
72.50
72.00
71.50
71.00
70.50
70.00
69.50
69.00
68.50
68.00
72.49
71.34
69.56
70.57
70.53
70.42
68.29
68.6
70.55
69.67
70.71
71.49
Unstored
Ventilated, Outside
Unventilated
Storage Bldg

Figure 5 shows mean values for the purity of beet juice and overall trends are similar to those seen with sugar content data. There are no statistically significant differences between treatments within the unstored, ventilated outside, or unventilated sample sets but for the storage building samples both dollar-sized crowning and full crowning resulted in samples with purities that are higher than uncrowned samples by a statistically significant amount. Dollar-sized crowned samples stored at ventilated outside and storage building locations were not significantly different than unstored samples.

Figure 5

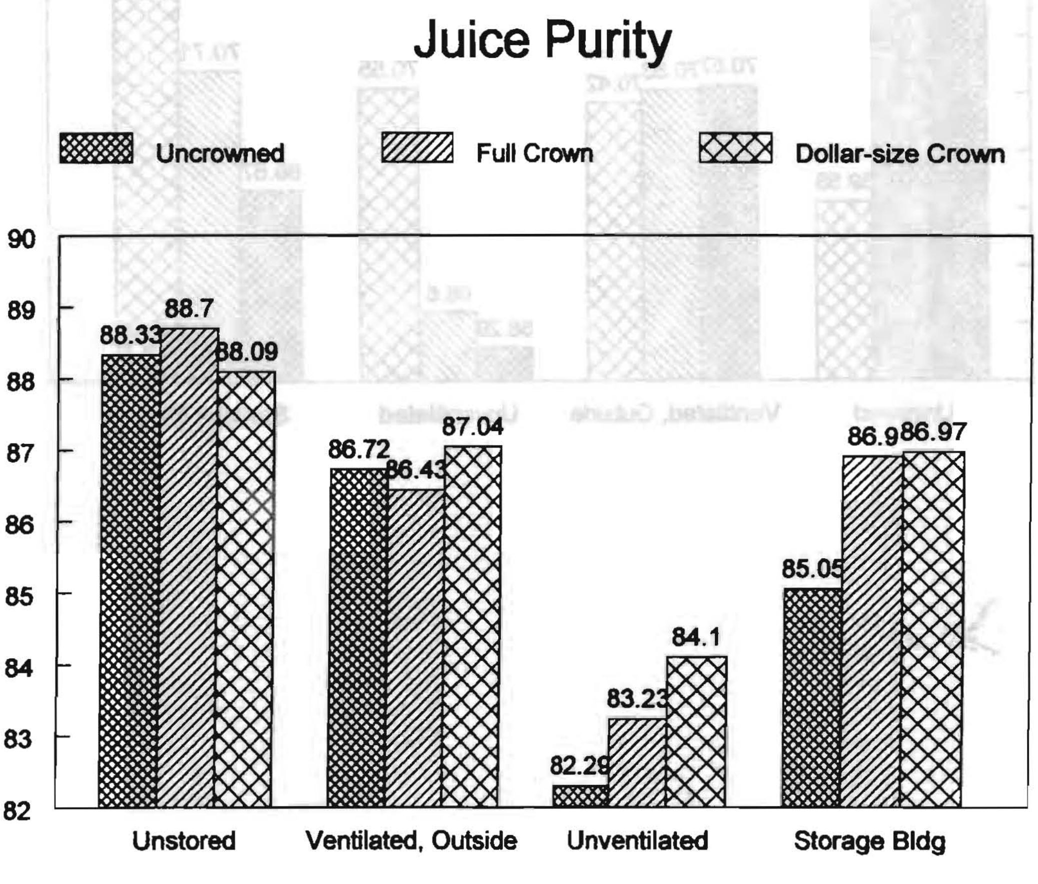


Figure 6 gives synthetic thin juice purity mean values. This procedure involves treating samples with lime and a precipitating agent to mimic the factory purification process. Differences follow the same general trends observed with sugar and juice purity data but the only statistically significant difference within a storage location is the difference between dollar-sized crowned beets and uncrowned beets in the storage building. In this case the mean values for all treatments at all three storage locations are lower than unstored values by statistically significant amounts.

Figure 6

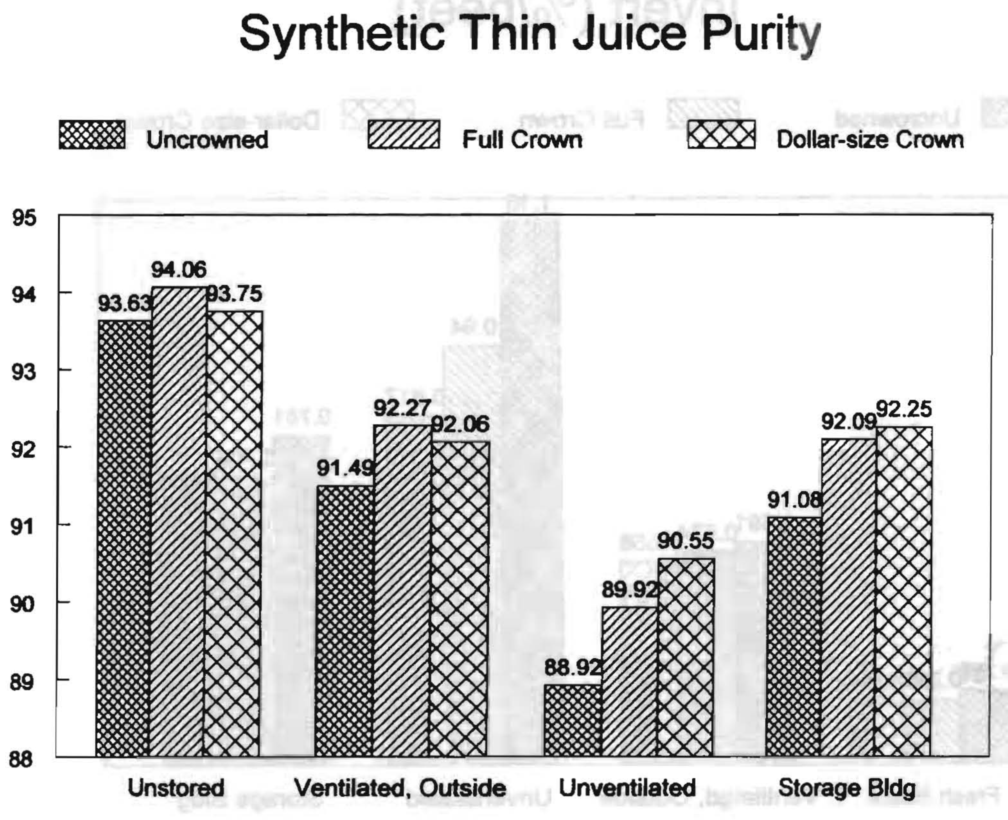


Figure 7 shows mean invert levels for sample sets. In this case, there are no statistically significant differences between treatments within storage locations. That is, even though invert levels appear to correspond reasonably well with the sugar content and purity trends observed in unventilated and storage building samples, variations within treatments are high enough that a paired t comparison does not show statistical significance. Comparisons between stored samples and their respective unstored treatments show statistically significant higher values for invert at all three locations for all three treatments.

Figure 7

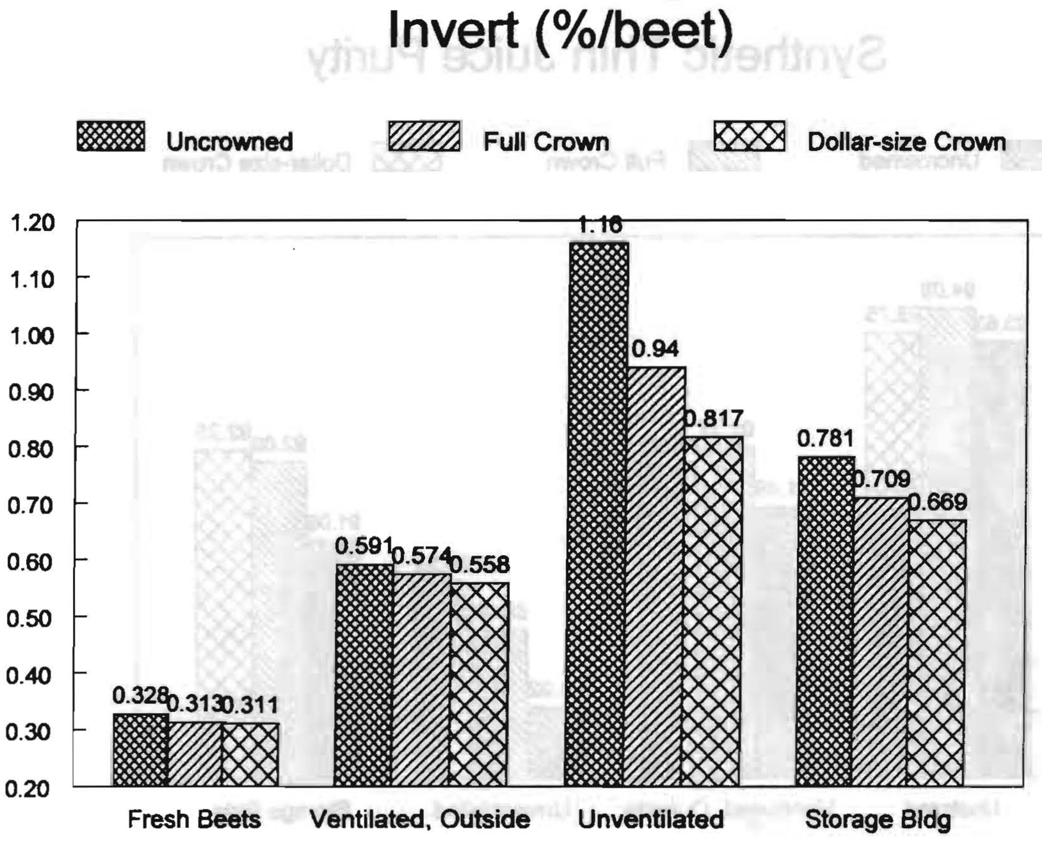
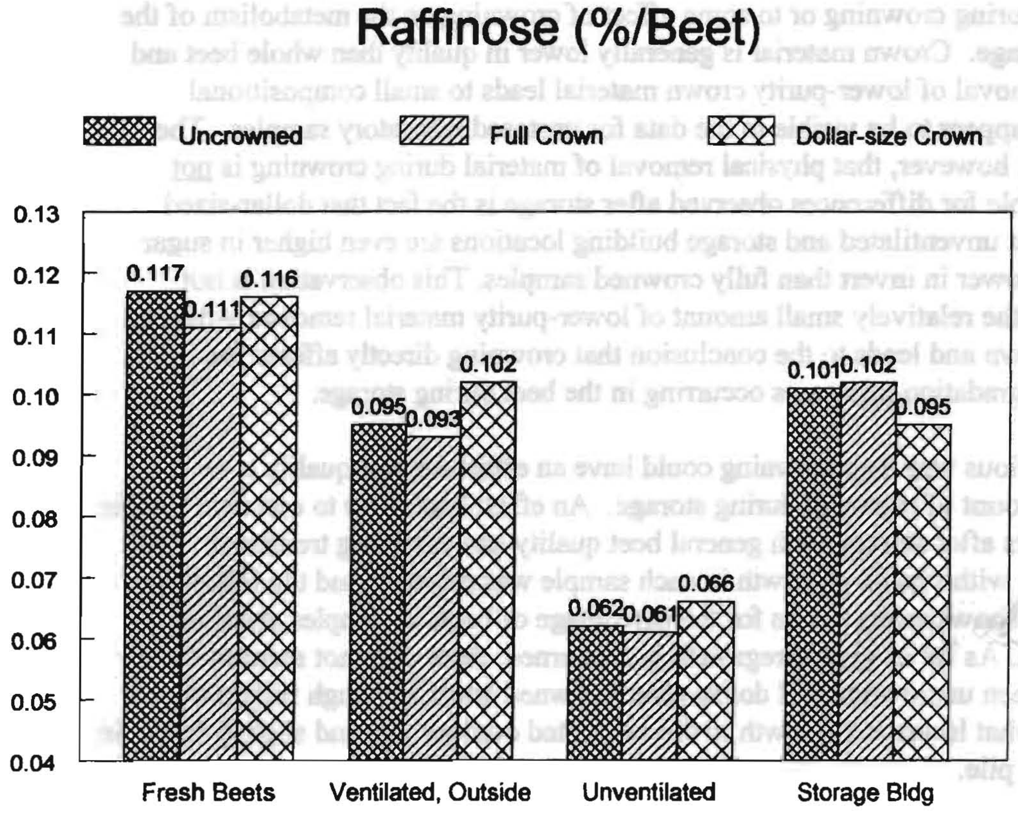


Figure 8 shows mean raffinose levels for all sample sets. Note that raffinose decreases with storage with nearly a 50% decrease in the poorer storage conditions of the unventilated pile. Differences between treatments within a storage location are not statistically significant at the 95% level but differences between unstored treatments and the respective stored treatment are statistically significant for all but the 4% crowned beets in the storage building.

Figure 8



B. Effect of crowning and storage on beet compositon.

Although, in the data given in Section A, differences for beet quality parameters are not always statistically significant, various measurements do seem to be consistent with the following observations:

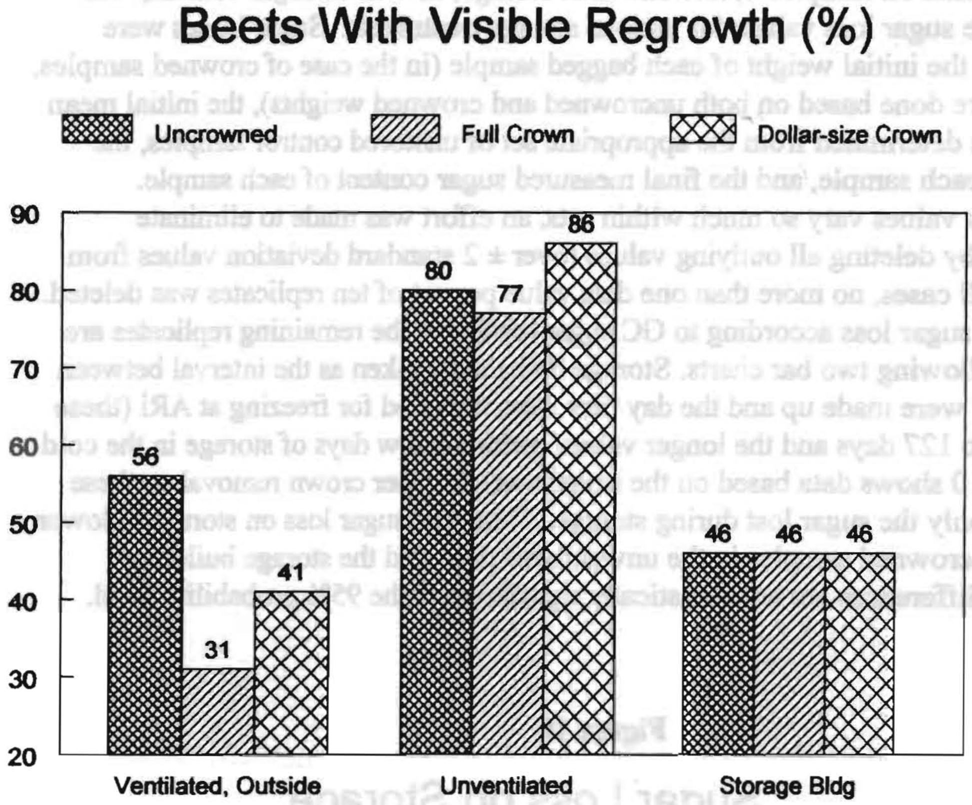
(1) Beets stored in the ventilated outside pile seem to have been under the most favorable storage conditions and, as a result, uncrowned beets are in relatively good condition and crowning treatments did not affect the quality much.

(2) At both the unventilated pile and the sorage building, uncrowned beets were generally the lowest in quality as indicated by sugar content (both GC and polarimetry), juice purity, synthetic thin juice purity, and invert. Beets fully crowned are usually better than uncrowned beets in quality but not as good as those with only a dollar-sized crown.

The better quality of crowned beets could be due either to the physical removal of non-sugars during crowning or to some affect of crowning on the metabolism of the beet during storage. Crown material is generally lower in quality than whole beet and the physical removal of lower-purity crown material leads to small compositional changes which appear to be visible in the data for unstored laboratory samples. The major evidence, however, that physical removal of material during crowning is not totally responsible for differences observed after storage is the fact that dollar-sized crowned beets at unventilated and storage building locations are even higher in sugar and purity and lower in invert than fully crowned samples. This observation is not consistent with the relatively small amount of lower-purity material removed with a dollar-sized crown and leads to the conclusion that crowning directly affects the metabolic or degradation processes occurring in the beet during storage.

One obvious way that crowning could have an effect on beet quality is to decrease the amount of regrowth during storage. An effort was made to correlate visible regrowth in beets after storage with general beet quality and crowning treatment. The number of beets with visible regrowth in each sample was recorded and the following table (Figure 9) shows mean values for the percentage of beets in samples showing visible regrowth. As far as visible regrowth is concerned, there does not seem to be any difference between uncrowned and dollar-sized crowned beets, although fully crowned beets are somewhat lower in regrowth in the ventilated outdoor pile and slightly lower in the unventilated pile.

Figure 9



Beets With Visible Regrowth (%)
Uncrowned
Full Crown
Dollar-size Crown
90
80
70
60
50
40
30
20
56
31
41
80
77
86
46
46
46
Ventilated, Outside
Unventilated
Storage Bldg

C. Sugar Loss and Recoverable Sugar Values

Weight data on samples before and after storage, as well as sugar content, was used to calculate sugar loss values for various storage treatments. Sugar losses were calculated from the initial weight of each bagged sample (in the case of crowned samples, calculations were done based on both uncrowned and crowned weights), the initial mean sugar content as determined from the appropriate set of unstored control samples, the final weight of each sample, and the final measured sugar content of each sample. Because the loss values vary so much within sets, an effort was made to eliminate extreme values by deleting all outlying values (over ± 2 standard deviation values from the mean). In all cases, no more than one data value per set of ten replicates was deleted. Mean values of sugar loss according to GC sugar levels for the remaining replicates are shown in the following two bar charts. Storage times were taken as the interval between the day samples were made up and the day they were chopped for freezing at ARi (these vary from 120 to 127 days and the longer values include a few days of storage in the cold room). Figure 10 shows data based on the sample weight after crown removal so these values include only the sugar lost during storage. Note that sugar loss on storage is lower for dollar-sized crowned samples in the unventilated pile and the storage building, although these differences are not statistically significant at the 95% probability level.

Figure 10

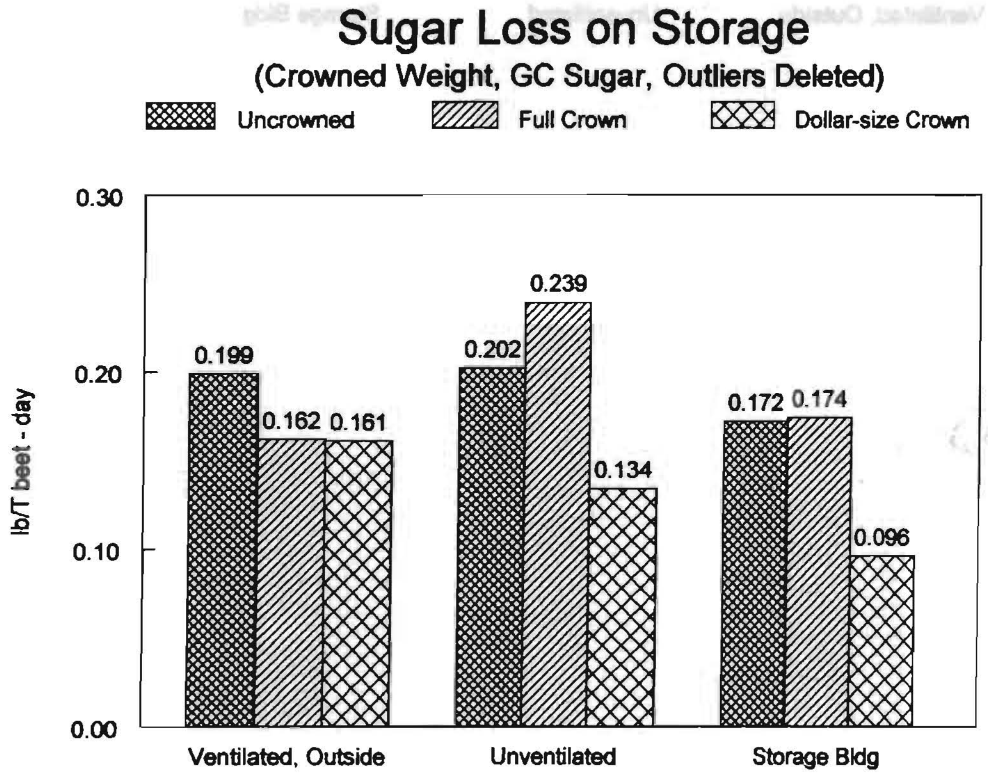
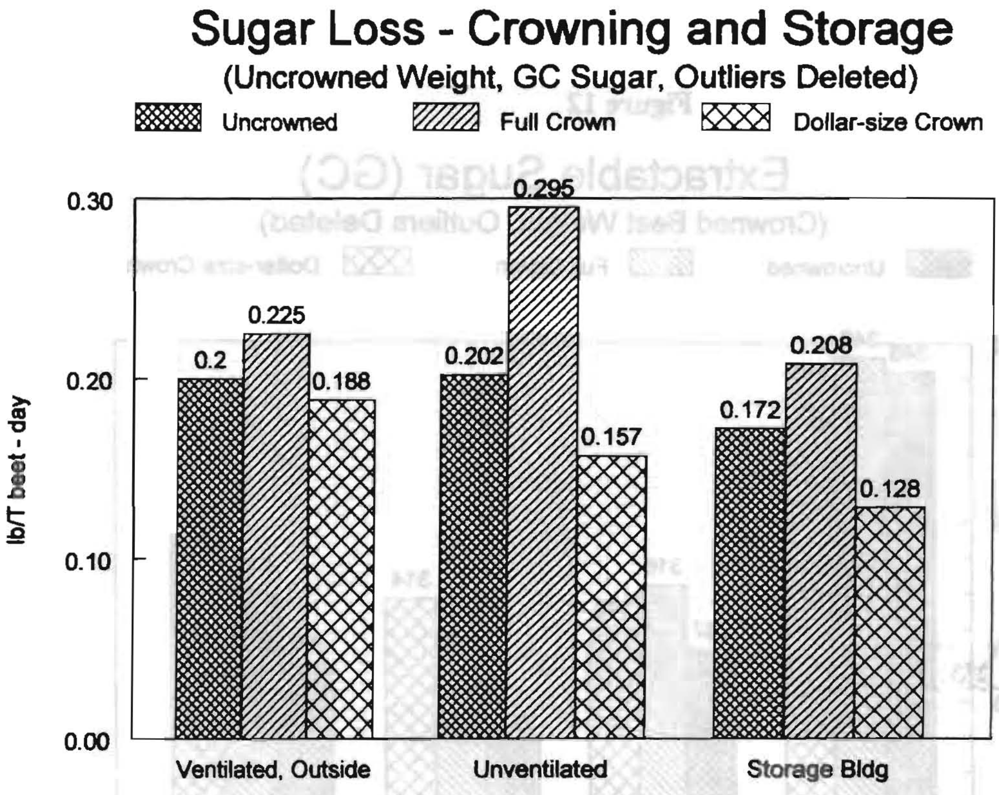


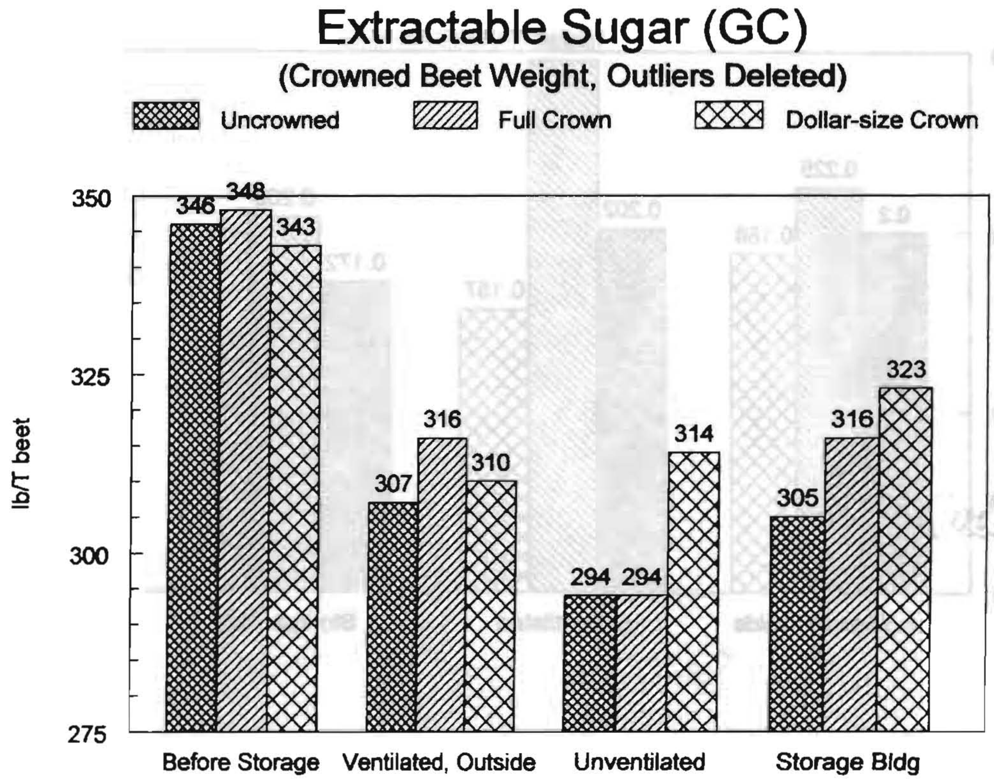
Figure 11 shows values based on the sample weight before crowning so these values actually include that sugar removed with the crown as well as sugar lost during storage. Losses based on the uncrowned weight naturally show higher values for fully crowned sample sets but dollar-sized crowned samples show lower sugar losses than either uncrowned or fully crowned beets. Of the data shown in Figure 11, the difference between mean values for unventilated pile fully crowned and dollar-sized crowned samples is statistically significant.

Figure 11



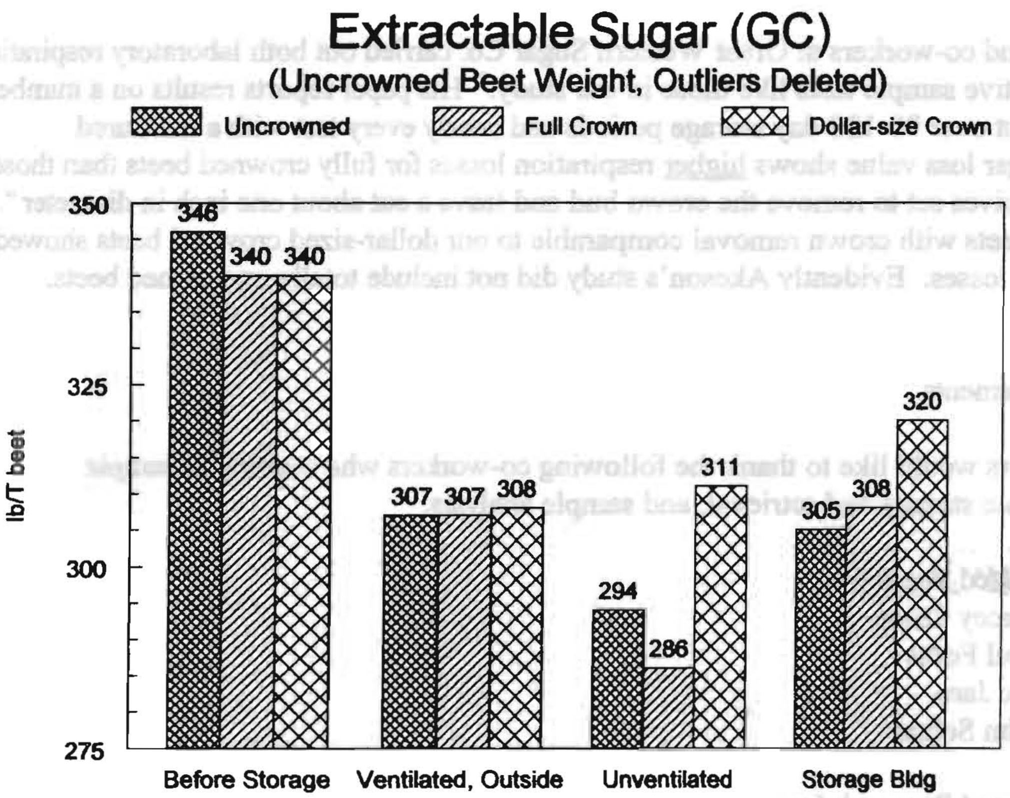
Recoverable sugar values are based on the appropriate sugar content after storage, the sample weight before and after storage, and synthetic thin juice purity. The recoverable sugar calculation neglects any factory losses except to molasses and assumes a final molasses of 60 purity (straight house recovery only). Recoverable sugar was then based on either beet weight as stored after crowning (Figure 12) or beet weight before crowning (Figure 13). Uncrowned and fully crowned beets in the unventilated pile were lower in recoverable sugar than any other samples but the dollar-crowned samples at that location are as high as the ventilated outside pile beets. The only difference between crowning treatments in Figure 12 that is statistically significant is between the storage building dollar-sized crowned and uncrowned samples.

Figure 12



As would be expected, basing recoverable sugar on the weight of beets as harvested (uncrowned weight, Figure 13) gives a noticeable decrease in recoverable sugar for fully crowned beets, due to the weight loss on crowning, but does not affect the dollar crowned recovery values much and they are still higher than uncrowned or fully crowned beets in the unventilated and storage building piles. Data in Figure 13 shows statistical significance for only the difference between unventilated dollar-sized crowned and fully crowned samples.

Figure 13



This study has shown a reasonably consistent trend of better storage characteristics for beets with a dollar-sized crown removed; particularly in the unventilated pile and the storage building. Full crowning resulted in final storage parameters in between dollar-size crowned and uncrowned beets but, with respect to sugar loss on storage and extractable sugar is offset by the material lost on crowning. Differences between crowning treatments were much less evident in samples stored in the outside ventilated pile.

These results are reasonably consistent with the results of several earlier studies. Steensen and Augustinussen in Denmark[1] reported the results of ongoing tests carried out through the 90's. The tests are all on beets stored in chambers so that respiration losses could be measured. Storage periods varied from 26 to 36 days. The authors reported slightly higher sugar losses and invert levels in beets topped with rubber flails than in those subjected to some scalping.

An earlier study by Wyse and Peterson reported on the investigation of various types of beet damage by measuring respiration rates.[2] Wyse and Peterson show some interesting plots of respiration rate versus time for hand-dug beets crowned to the lowest leaf scar and uncrowned beets. The damage caused by crown removal results in an increase in respiration rate for the first four days but the rate then drops to below the rate for a uncrowned beet. The authors state that the respiration rate is ultimately lower for a crowned beet because respiration rate for crown tissue is about three times the rate of a topped root. Wyse and Peterson compared respiration rates for various treatments over a 95 day period.

Akeson and co-workers at Great Western Sugar Co. carried out both laboratory respiration rate tests and captive sample tests like those in our study.[3] His paper reports results on a number of tests carried out over 90-120 day storage periods and nearly every test with a measured respiration or sugar loss value shows <u>higher</u> respiration losses for fully crowned beets than those with " scalper knives set to remove the crown bud and leave a cut about one inch in diameter". In other words, beets with crown removal comparable to our dollar-sized crowned beets showed lower respiration losses. Evidently Akeson's study did not include totally uncrowned beets.

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V. References

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