Seasonal Variations in the Nonsucrose Content of Several Straight House Process Streams

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Introduction

During the past several years many of the process streams in our beet factories have been analyzed for a variety of nonsucrose constituents. This work has been confined primarily to factory liquors from our Woodland, California Steffen house (4)[2].

Another investigation was made during the 1970 crop year. The crop year consists of a 1970 fall and 1971 spring campaign. In this study sampling was done at our Manteca, California straight house operation. The main purpose of choosing a straight house operation was to avoid any possible anomalies in the nonsucrose profile due to recirculation patterns characteristic of Steffen house operations.

The primary purpose of this work was threefold: (a) to determine the trends in the nonsucrose constituents of beets sliced; (b) to determine what nonsucrose constituents are eliminated by the diffusion and carbonation processes; (c) and finally, to determine if a consistent association could be found between certain nonsucrose data and various factory statistics.

Materials and Methods

Hourly samples of cossettes, diffusion juice, and thin juice were collected and frozen immediately at –20°C. The samples were composited on a weekly basis.

Methods of analyses used have been reported in a previous paper (4). The only change has been in the method of determining the nitrate ion.

The nitrate ion is determined potentiometrically using an Orion Model 92-07 nitrate electrode and Model 90-02 double junction reference electrode. All samples and nitrate standards are diluted 1:1 with a buffer solution developed by Milham et al.(3). The buffer solution reduces errors due to ionic strength and chemical interferences which are present in the samples.

Previous investigations have indicated that significant chemical changes occur in some stored samples of beet cossettes, brei, and water extracts even though they have been stored at –20°C(6).

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[2] Numbers in parentheses refer to literature cited.

The most notable change has been a decline in the polarization value. In order to circumvent this possible source of error all polarization and apparent purity data reported were obtained by factory personnel on the fresh sample. The fresh samples were also analyzed for conductivity ash.

Results and Discussion

A plot of the data for solids found in beets sliced at the Manteca factory during the 1970 crop year will be found in Figure 1. Although the plot shown represents data from only one crop year of beets, it is a pattern which has been duplicated in previous years. It has been found that only the levels of the different solids vary extensively from year to year.

One of the most noticeable patterns depicted in Figure 1 occurs in August. Beets being sliced at that time have relatively low concentrations of total solids, sugar, and marc. Unfortunately this coincides with a period when the concentration of nonsucrose constituents is the highest.

During the remainder of the fall campaign and most of the spring campaign, total solids increase in the beets being sliced at our Manteca factory. This change is due primarily to an increase in both sugar and marc. The soluble nonsugar content of beets sliced at Manteca actually declines during this period. Because of the divergent trends in the sugar and soluble nonsugar solids, there is a significant increase in the resulting apparent purity coefficient(apc) of the beets.

During the last six weeks of the 1971 spring campaign, total solids declined in beets sliced. This is reflected in all of the various solid fractions plotted in Figure 1.

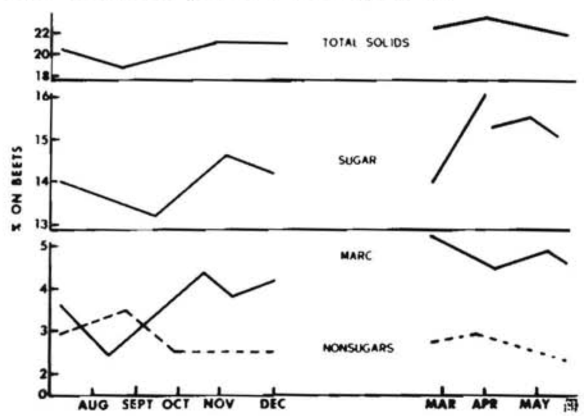

Figure 1.—Nonsugar content of beets sliced at Manteca factory.

The various soluble nonsucrose constituents associated with beets sliced at the Manteca factory during the 1970 crop year have been categorized as either *nitrogen containing compounds, inorganic compounds,* or *other organic componds.* The amount of nonsugars accounted for in the latter category is determined by subtracting the quantities found in the first two categories from the total nonsugar figure.

A plot of the relative portion of each category of nonsugar found in beets sliced at the Manteca factory during the 1970 crop year will be found in Figure 2. The ratios of the nonsugar fractions change considerably during the crop year. This is especially true for beets processed during the spring campaign.

Nitrogen compounds account for 30% to 50% of the nonsucrose fraction of beets processed during the spring campaign. The plot in Figure 2 indicates that the relative amount of this fraction diminishes as the spring campaign progresses. A similar pattern has been reported in earlier work(5).

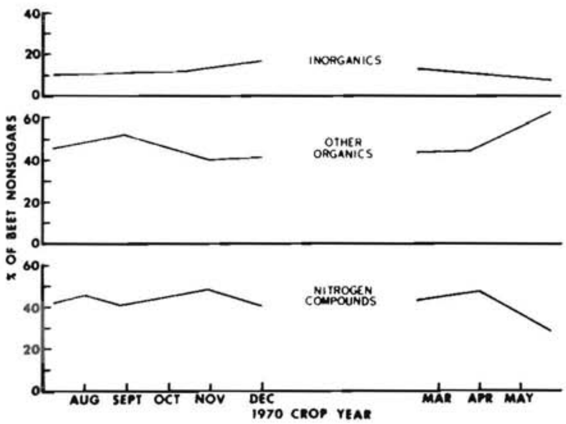

Figure 2.—Nonsugar content of beets sliced at Manteca factory.

The *inorganic compound fraction* also declines during the spring campaign. This fraction accounts for approximately 12% of the nonsucrose constituents in beets sliced during February but decreases to 8% by the end of the spring campaign. This trend has been found to be characteristic of beets processed during a spring campaign(5).

The *other organic compounds fraction* of beets sliced at Manteca accounts for an increasing portion of the total nonsugars as the spring campaign continues. This trend has also been noted during previous years(5). During the May period, the *other organic fraction* accounts for approximately 60% of the nonsucrose constituents found in beets sliced.

The change in the ratio of the three major nonsugar fractions in beets sliced at Manteca during the fall campaign is not of the same magnitude as found in spring beets. The *nitrogen containing compounds* account for 38-48% of the total nonsugars. Maximum values occur during both the August and November periods. The *inorganic fraction* accounts for a progressively larger portion of the beet nonsugars as the fall campaign continues.

The average amount of nonsugars associated with beets sliced at Manteca during the fall and spring campaigns is tabulated in Table 1. The total nonsugar content of spring processed beets decline approximately 5% in relation to beets sliced in the fall. The decline is due entirely to a 10% reduction in the *nitrogen containing compounds* and a 20% reduction in *inorganic compounds.*

Table 1.—Nonsugar content of beets sliced at Manteca factory (1970 crop year).

Nonsugar fraction	Fall campaign % on beets	Fall campaign Rel %	Spring campaign % on beets	Spring campaign Rel %
Nitrogen CMPDS	1.22	43	1.09	41
Inorganic	0.35	13	0.28	10
Other organic	1.25	44	1.31	49
Total	2.82	100	2.68	100

The quantity of the *other organic compounds* actually increases in the older more mature beets which are sliced during the spring campaign. Because of the relatively high factory operating efficiency experienced during spring operations, the data in Table 1 suggest that the *other organic fraction* might not be as detrimental to factory operations as nonsugars in the other two categories.

The data for each of the three nonsugar fractions has been compared to the percent sugar extraction data collected at Manteca during the 1970 crop year. The resulting correlation coefficients are: inorganic fraction –0.64; nitrogen compounds fraction –0.57; other organic compounds fraction –0.25.

The *nitrogen containing compound fraction* has been separated into four categories. A list of the data will be found in Table 2. Most of the individual nitrogen compounds follow the

Table 2.—Nitrogen content of beets sliced at Manteca factory (1970 crop year).

Nitrogen compound	Fall campaign % on beets	Fall campaign Rel %	Spring campaign % on beets	Spring campaign Rel %
Amino-N	0.42	34	0.32	29
Nitrate-N	0.03	3	0.04	4
Betaine-N	0.16	13	0.19	17
Other-N	0.61	50	0.54	50
Total-N	1.22	100	1.09	100

same general concentration trend in the beet as the total nitrogen figure. This is especially true of the *amino acid* and *other nitrogen compound fractions*. In fact the correlation coefficient between *total-N* and *amino-N* is +0.84 and highly significant. The 10% decline in the *total nitrogen* content of spring beets is due primarily to a reduction in *other nitrogen compounds*. There is also a slight reduction in *amino-N*.

Both the *betaine* and *nitrate* fraction increase in spring campaign beets. This is especially true for *betaine* and is the primary reason for the poor association which exists between it and the *total nitrogen* fraction. Only during the last two weeks of the spring campaign do beets sliced at Manteca show a reduction in *betaine*. A previous study had suggested that the betaine content remains relatively high in spring beets(5).

A summary of the data for the *inorganic constituents* associated with beets sliced at Manteca during the 1970 crop year will be found in Table 3. Potassium accounts for over 50% of the *inorganic compound fraction*. The results from other studies confirm the quantitative importance of this ion in the *inorganic fraction* (4, 5).

Table 3.—Inorganic content of beets sliced at Manteca factory (1970 crop year).

Inorganic	Fall campaign % on beets	Fall campaign Rel %	Spring campaign % on beets	Spring campaign Rel %
Potassium	0.19	54	0.16	57
Sodium	0.06	17	0.04	14
Chloride	0.06	17	0.03	11
Other*	0.04	12	0.05	18
Total	0.35	100	0.28	100

*Calcium plus magnesium

Both sodium and chloride contribute significantly to the *inorganic fraction*. These two ions and potassium all follow the same general concentration trend as the total inorganic fraction. Quite possibly, they could be used to estimate this quantity in beets.

The *other fraction* of the inorganic compounds is composed of calcium and magnesium. The concentration of either one in the beet is so small that they were combined under one category. Magnesium is usually at a higher concentration than calcium. However, the increase in the concentration of the *other fraction* in spring beets is due primarily to a change in the calcium content.

A study has been made on the elimination of the various nonsucrose constituents by the Manteca diffusion and carbonation processes. A plot of the data for nonsugars eliminated by each process during the 1970 crop year will be found in Figure 3. The plot shows quite clearly that the percent of total nonsugars removed by the diffusion and carbonation process varied considerably during the 1970 crop year. It ranges from a low of 27% in July to almost 60% the following May.

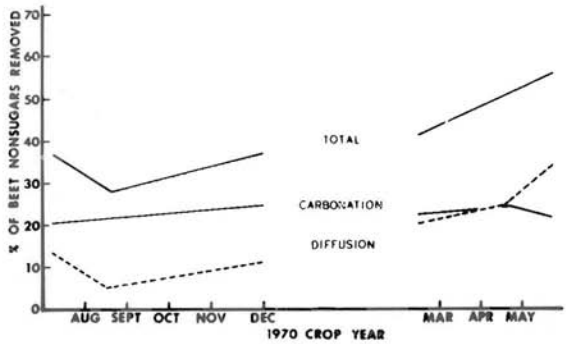

Figure 3.—Elimination of beet nonsugars at Manteca factory.

The primary cause for the wide fluctuation in the relative amount of nonsugars removed at Manteca is due to differences in diffusion elimination. This process removed from 3% to 36% of the nonsguars found in beets processed at Manteca during the 1970 crop year. In comparison the carbonation process removed between 20-25%

It is quite possible that the wide fluctuations in the percent of beet nonsugars removed by the diffusion process is due to a difference in the methods used to extract the soluble solids from the beet. In the factory operation (diffusion process) the beets are sliced into cossettes which are then subjected to a countercurrent extraction with warm water. The cell contents must first pass through very small openings in the cell wall. The size of these holes is such that macro-molecules of pectins, albumins, etc. are not allowed to pass through. However, fragments of these chemicals are leached out. This is why diffusion juice is harder to purify than say, pressed juice (2).

In comparison, the method of extraction used in the laboratory is one which maximizes the amount of soluble solids extracted from the beet. Beets are passed through a Spreckels saw. The resulting brei is then blended with boiling water for five minutes using a Waring blender. In all probability the beet cell wall is destroyed. If so, this would allow all soluble substances to be present in the extract regardless of molecular weight. Quite possibly this would include some short chain pectic substances.

Kertesz has indicated that the more mature beet would contain more pectic substances than a relatively young beet(1). If so, we would expect beets processed in the spring to have relatively large amounts of pectin as compared to beets processed in the fall. If our previously explained hypothesis on extraction is true, one would expect the laboratory extract of the spring beets to contain an appreciable amount of pectic materials as compared to either the laboratory extract of fall beets or the extract of the diffusion process. If these pectic materials are soluble, the resulting apc will be adversely affected. Furthermore, when the beet apc value is compared to the appropriate diffusion juice apc, the apparent nonsugar elimination by the diffusion process will be artificially inflated. The rather large elimination of nonsugars by the diffusion process which occurred during the 1971 spring campaign could be due to a systemic error in the beet apc method.

The amount of each major nonsugar fraction removed by the Manteca diffusion process during the 1970 crop year is tabulated in Table 4.

Table 4.—Elimination of beet nonsugars by the Manteca diffusion process (1970 crop year) % on beets.

Nonsugar fraction	Fall campaign		Spring campaign	
	Cossettes	Eliminated	Cossettes	Eliminated
Nitrogen CMPDS	1.22	0.19	1.09	0.25
Inorganic	0.35	(0.02)	0.28	—
Other organics	1.25	0.08	1.31	0.41
Total	2.82	0.25	2.68	0.66

The diffusion process removed approximately 9% of the nonsugars in beets sliced during the fall campaign. These were primarily in the form of *nitrogen compounds.* The only nitrogen fraction affected significantly was the *other nitrogen compounds.*

During the spring campaign, approximately 25% of the beet nonsugars were removed by the Manteca diffusion process. This increased elimination is due almost entirely to removal of the *other organic compounds fraction.* These compounds might be in the form of pectic substances.

Over 20% of the *nitrogen compounds* in beets sliced during the spring campaign were removed by the diffusion process. These were primarily in the form of the *other nitrogen compounds fraction.* However, it also included approximately 24% of the beet *amino-N.*

A list of the nonsugars removed by the carbonation process at the Manteca factory during the 1970 crop year will be found in Table 5. The type and amount of nonsugar removed remains relatively constant throughout the crop year. Approximately 60% of the nonsugars eliminated are from the *other organic fraction.*

Nitrogen compounds account for the remaining 40% of the beet nonsugars removed during carbonation. This consists of 75% *other nitrogen compounds* and 20% *amino-N.* The remaining reduction is due to the removal of small amounts of *betaine.*

In a similar study conducted at a Steffen house, it was found that a larger portion of the nitrogen compounds were removed as the campaign extended into June(4). Quite possibly a similar pattern would have occurred in this data had the campaign continued.

Table 5.—Elimination of beet nonsugars by the Manteca carbonation process (1970 crop year) % on beets.

Nonsugar fraction	Fall campaign		Spring campaign	
	Cossettes	Eliminated	Cossettes	Eliminated
Nitrogen CMPDS	1.22	0.23	1.09	0.22
Inorganic	0.35	0.01	0.28	0.02
Other organic	1.25	0.41	1.31	0.38
Total	2.82	0.65	2.68	0.62

In most studies into the nonsugar content of beets and factory juices, there is usually an attempt made to determine if any usable relationships exist between these data and certain important factory statistics. This study is no exception.

It has been found that highly significant correlation coefficients exist between many of the nonsucrose and factory data collected during the 1970 crop year. A few of the more interesting ones are listed as follows:

beet apc vs. beet percent sugar	+0.80
beet apc vs. beet percent nitrate	–0.89
beet total-N vs. beet amino-N	+0.89
beet conductivity ash vs. beet total inorganics	+0.90
thin juice purity vs. beet conductivity ash	–0.74

There are many more relationships which have been found to be equally good. However, including them in this report would be superfluous due to the fact that in most cases the regression equations are only applicable for a specific time period. This is true even though the correlation coefficients remain somewhat constant. For example, we found a correlation coefficient of 0.90 between the percent sugar and apc values for beets sliced at Manteca during the 1968 crop year. A similar association was found the following year. However, the respective regression equations are quite different. A plot of the regression lines for each equation will be found in Figure 4.

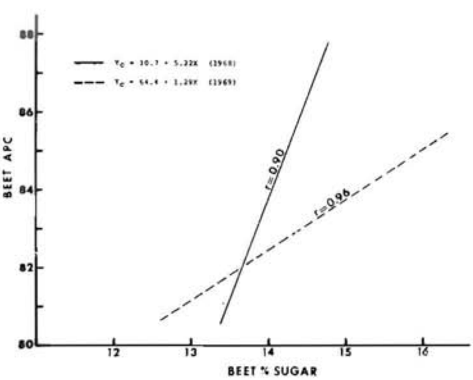

Figure 4.—Beet apc v.s. beet % sugar Manteca factory.

It should be mentioned that this problem is not unique for just this particular data. Over the past few years we have tried to use regression equations, developed by many notable workers in the field of sugarbeet research, as a means to predict various factory statistics. However, the results also have been inconsistent. The inconsistencies are due in part to the length of our operating periods.

Examples of some of the inconsistencies found in various relations developed during the fall and spring campaigns of the 1970 crop year can be found in Figures 5, 6, and 7. In addition, Figure 7 shows the inconsistency of the relationship between beet apc and beet conductivity ash during two successive fall campaigns. There are other equally inconsistent regression equations which are not included in this report.

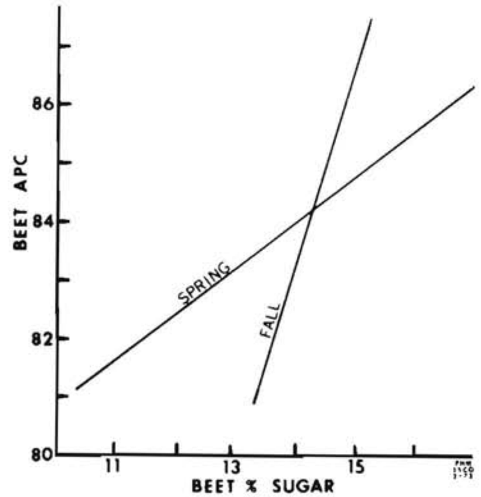

Figure 5.—Beet apc v.s. beet % sugar Manteca factory 1970 crop year.

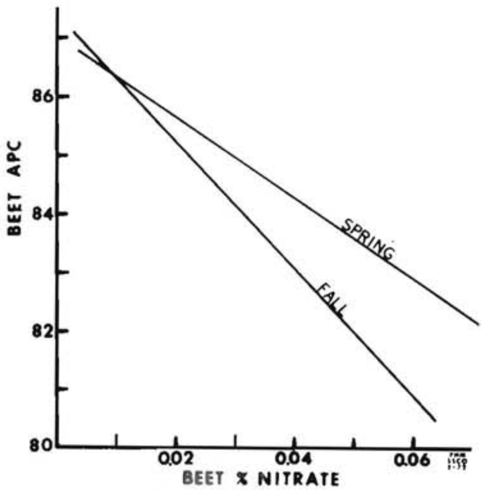

Figure 6.—Beet apc v.s. beet % nitrate Manteca factory 1970 crop year.

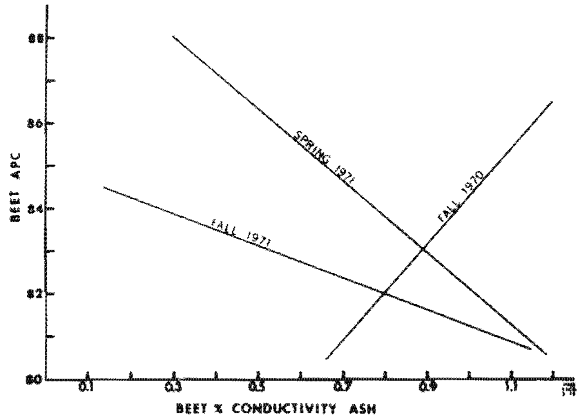

Figure 7.—Beet apc v.s. beet % conductivity ash Manteca factory 1970-71.

We have, however, found one relationship which is quite constant from campaign to campaign and also from year to year; that is, the association between beet apc and sugar in molasses as a percent of sugar entering (Figure 8). It has been found to be relatively constant during four of the last five crop years. The data for the 1967 crop year have been excluded because the Manteca factory was being fitted with new equipment.

We have also included a plot of the regression equation developed from 1971 fall campaign data in Figure 8. It can be seen that the slope of the line compares quite favorably with the plots from previous years.

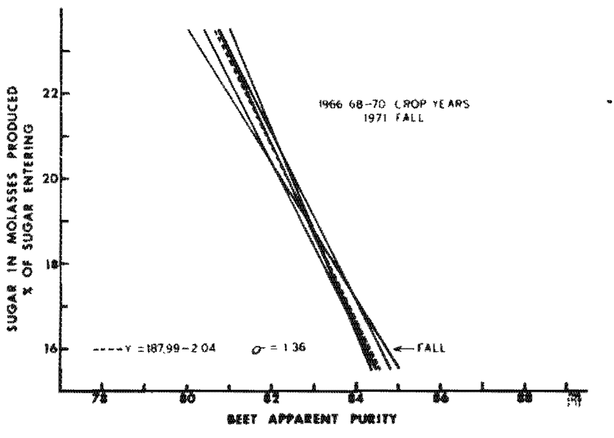

Figure 8.—Sugar in molasses v.s. beet apc Manteca factory.

It has been concluded that the beet apc value can be used as a means of predicting what portion of the sugar in beets sliced will ultimately end up in molasses and thus not be extracted. However, the apc method is quite time consuming. At the present time we are trying to find a parameter which is consistently associated with the beet apc and which can be easily determined; perhaps even automatically. It would then be possible to assign a "quality index" to sugarbeet roots.

Summary

During the 1970 crop year, hourly samples of cossettes, diffusion juice, and thin juice were composited on a weekly basis and analyzed for various compounds. Cossettes contained an average of 2.8% nonsugars during the 10-month campaign. The figure was generally higher in the fall than spring.

The composition of the nonsugar fraction was 47% *other organic compounds,* 42% *nitrogen compounds,* and 11% *inorganics.* The relative concentration of the latter two nonsugar fractions was higher during fall operations.

Nonsugars removed by the factory process ranged from 27% to 60% of those entering. The higher elimination was associated with spring operations. The diffusion process removed from 3% to 36% of the cossettes nonsugars. The wide fluctuation was due primarily to the amount of the *other organic fractions* eliminated. This fraction accounted for over 60% of the total nonsugars removed from spring cossettes as compared to only 30% in the fall. *Nitrogen containing compounds* account for the remaining portion of the nonsugars removed by the diffusion process.

The carbonation process removed between 20-25% of the nonsugars entering the factory. Sixty percent were in the form of *other organic compounds* and the remainder, *nitrogen compounds.* No seasonal differences were evident.

Various associations have been found between some of the nonsugar data and factory statistics. However, most of the relationships were subject to seasonal variations. One exception to the rule was the relationship between beet apparent purity and sugar in molasses as a percent of sugar entering. The estimating equation has been found to be quite consistent during the last 6 years.

Acknowledgment

To Terry Morrill, laboratory technician, for performing most of the analytical analyses.

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