SUGAR COMPONENTS OF SWEET CORN CULTIVARS AS INFLUENCED BY MATURITY PATTERNS

By

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INTRODUCTION

An ear of sweet corn goes through many physical and chemical changes from the day the silks appear until the day it is harvested. Many of these greatly influence the flavor and keeping quality of the sweet corn ear. The changes in sugars occurring in the developing sweet corn ear probably have the greatest effect on the flavor. There may be changes in the total sugar content, or in the type of sugar present both of which are important in determining flavor.

Much work in determining the sugar changes in maturing sweet corn was done between 1919 and 1940. Since 1940, however, very few contributions have been made in determining the sugar components in maturing corn. The work which has been done only separated the sugars into the reducing and the non-reducing components.

The purposes of this study were (a) to determine the components of the reducing sugar fraction; (b) to determine the percent of change of these components as the ear matures; (c) to determine differences in sugar components in three different cultivars and (d) to determine the effect of time of day of harvest on the percent of each sugar component.

REVIEW OF LITERATURE

Straughn and Church (13) showed that there was no direct relation between the latitude in which the corn was grown and the sugar content. Straughn (12), working with Stowell's Evergreen variety in Maryland reported that in freshly pulled samples 4.59 to 4.74 percent total sugars were found on a fresh weight basis. On standing 24 hours at room temperature, unhusked, about one-third of the sugars disappeared. After this, the loss continued until the sugars reached 1.80 percent.

Stevens (11) found that sweet corn deteriorated very rapidly after it was picked. He also found that the rate of deterioration depended upon temperature. Furthermore, he found temperatures at which the corn was held after picking also caused marked differences in the rate of deterioration.

Appleman (2) in 1920, observed that in very early stages of maturity of sweet corn ears the reducing sugars predominated but very rapidly decreased as ripening proceeded. He also found that the percentage of sucrose increased until a maximum was reached and then decreased as the starch content increased.

Appleman (1) also found that the depletion of sugar in green sweet corn after it was separated from the stalk did not proceed at a uniform rate but became slower and slower until finally the loss of sugar ceased when the initial total sugar had decreased about 62 percent. He found that most of the decrease in the percentage of sugar in green sweet corn during storage was due to conversion to polysaccharides, chiefly starch.

Huelson (7) stated that the total sugars increased as the ear matured until 15 days after silking and then it started to decrease. He also stated that the reducing sugars showed large decreases as the ear matured. He said that non-reducing sugars increased during the first 15 days after which there was a slow decrease. Huelson also stated that dry matter constantly increased and that this explains why corn may not have the sweetest flavor at the time the sugars reach their maximum. The constant increase in dry matter and decrease in moisture content concentrated the sugars and the corn was therefore at its sweetest several days after the nonreducing sugars reached their peak.

Magoon and Culpepper (8) found that the total sugar content of the very young grains was medium to low, increased for a time as development proceeded and then decreased as maturity approached. The rate at which the changes occurred depended primarily on the prevailing temperature. They also

discovered that sucrose was low in the early stages of development increased rapidly for a time, and then decreased slowly until maturity was complete. The changes were also affected by the prevailing temperature. In the cool autumn there was a greater proportion of sugars as compared with polysaccharides than in the earlier plantings. These researchers stated that the reducing sugars were high in the early stages of development of the corn and decreased steadily as maturity advanced, the rate depending on the temperature.

Winter, Nylund, and Legun (15) found that the sugar content of both precooled and non-precooled sweet corn declined during the first 30 hours after harvest with the non-precooled corn losing approximately three times as much sugar as the precooled. They also discovered that between 30 and 54 hours after harvest little or no sugar losses occurred in either precooled or non-precooled corn while flavor scores continued to decline. They observed that the correlation coefficient between sugar content and taste panel scores of precooled and non-precooled sweet corn showed that the flavor was influenced more by variation in sugar content when the sweet corn was relatively low in sugar than when it was relatively high. This indicated that when the sugar level of sweet corn was sufficiently high, other variables become more important in determining the relative palatability of the sweet corn samples tested.

MATERIALS AND PROCEDURES

Three sweet corn cultivars and three dates of planting furnished the samples used in this study. The cultivars were Sugar King, Tendercrisp, Super Sweet. The dates of planting were May 4, May 22 and June 2. All the plots were planted on Sarpy fine sandy loam of the Kansas Agricultural Experiment

Station at Manhattan, Kansas. The plots were fertilized and then were irrigated at frequent intervals throughout the study. The silks were tagged by date of appearance. The tags were dated and tied around the stalk just above the ear. Many ears and stalks of the first planting were severely damaged by hail; however, damaged ears were avoided when harvesting samples. High temperatures at the time of silking of the second planting resulted in a number of poorly pollinated ears. These ears were avoided when harvesting samples. The ears were picked at 10 days, 15 days, and 23 days to represent the blister, milky and doughy stages of maturity for the first date of planting. Temperatures were considerably higher during development of the ears of the later two plantings. This caused the ears of the later stages to be in the milky stage, or the proper stage for eating, at 10 days from silking while ears of the early planting did not reach the milky stage until 15 days after silking. Therefore, to alleviate this problem, the samples were categorized according to the number of degree-hours from silking. The number of degree-hours per day was calculated by taking the mean temperature and subtracting a base temperature of 50° F. This value times 24 hours per day was used to determine degree-hours per day. (5) The degree-hours per day were calculated for the days between the date of silking and the date of harvest. The values obtained for each of these days was added to give the number of degree-hours from silking. All the samples were picked at 5:30 A.M., except those samples used to determine the effect of time of day on the sugar content. As soon as the samples were picked they were placed in an ice chest and hauled immediately to the laboratory where the sugars were extracted.

Procedures Used for Extracting the Sugars From the Corn Kernels

1. All the kernels were cut from the entire ear at a uniform depth.
2. From these freshly cut kernels, a 25 gram random sample was obtained.
3. The 25 gram sample was placed in an omni-mixer with approximately 100 ml. of 95% ethanol.
4. The corn-ethanol mixture was then blended for one to five minutes depending on the maturity of the corn sample.
5. The blended mixture was filtered with a Buchner funnel containing a layer of supercel. The supercel was used to speed up the process of filtering. The filtering process usually took from 20 to 30 minutes.
6. The residue was washed with 75 percent ethanol.
7. The filtrate was then diluted to a volume of 500 ml. with 95 percent ethanol. The corn extract in the ethanol solution was stored until the sugar analyses were completed.

Procedures Used in Qualitatively Determining the Sugars Present In Sweet Corn

1. Standard solutions of glucose, fructose, xylose, mannose, and galactose were prepared.
2. A line was drawn on Whatman No. 1 filter paper 1 inch from one of the edges. Then, small pencil marks were made at 1 inch intervals along this line.
3. One drop of the five standard sugar solutions was placed on every other mark and allowed to dry.
4. One drop of corn extract solution was placed on the remaining marks and allowed to dry.

5. This paper was placed in a container containing 80 ml. of n-butyl alcohol, 30 ml. glacial acetic acid and 50 ml. of water. The paper was left in the container until the solvent had risen near the top.
6. The paper was taken out of the container and marked at the point to which the solvent had risen. The chromatogram then was allowed to dry.
7. The paper was placed in a tray containing a saturated solution of silver nitrate in acetone.
8. After the paper was thoroughly wet, it was removed and the acetone was allowed to dry. Then, the paper was placed in a tray containing four grams NaOH per 100 ml. methanol. Dark spots appeared on the paper wherever there were reducing substances.
9. The distance the solute moved was measured by finding the distance between the mark on the base line and the center of the spot.
10. The distance the solvent traveled was measured by finding the distance between the line where the solutes were applied and the line indicating how far the solvent had risen.
11. The Rf for each solute was calculated by dividing the distance the solute moved by the distance the solvent moved.
12. The R_f of the standard sugar solutions were then compared with the Rf of each spot of the corn extract.

Procedures Used for Preparing Solutions for Sugar Analysis From The Alcoholic Corn Extract Solution

1. Twenty-five ml. of corn extract solution was pipetted into a 250 ml. beaker.

2. The beaker of corn extract solution which contained approximately 80 percent alcohol was placed on a steam plate and heated for at least a half hour to remove the alcohol.
3. After all the alcohol was removed, the solution was diluted to 250 ml. with distilled water to form solution A. At this time, normally, the next step would be clarification in which lead acetate and sodium oxalate are added to the solution, but after running several tests with and without clarification, it was found that clarification was not needed.

Reagents Used in Making Sugar Analysis (14)

Alkaline Ferricyanide solution was made by mixing 160 grams of anhydrous sodium carbonate, 80 grams of anhydrous disodium phosphate, 4 grams of potassium ferricyanide and enough distilled water to bring to one liter volume.

Arsenomolybdate solution was made by dissolving 25 grams of ammonium molybdate tetrahydrate in 450 ml. of distilled water. Then, 21 ml. of concentrated sulfuric acid was added, followed by 3 grams of disodium arsenate dissolved in 25 ml. of water. The solution was heated at 55° C. for 30 minutes in a water bath with constant stirring.

Procedure Used for Obtaining the Concentration of Total Sugars From the Corn Extract

1. A 50 ml. aliquot of solution A was pipetted into a beaker containing 5 ml. of concentrated hydrochloric acid and allowed to stand over-night to hydrolyze the sucrose to glucose and fructose.
2. After this solution had stood over-night it was neutralized with 40% NaOH with the aid of a pH meter.

3. The neutralized solution was diluted to 100 ml. to form solution B.
4. A 2 ml. aliquot of solution B was placed in a test tube to which 5 ml. of Ferricyanide solution was added.
5. The tubes containing solution B and Ferricyanide solution were placed in boiling water for 10 minutes.
6. After rapidly cooling the solutions 10 ml. of 2N H_2SO_4 was added to neutralize them.
7. Four ml. of the arseno-molybdate solution was added to each solution.
8. The green solution which resulted was diluted to 100 ml. and allowed to stand for at least 15 minutes.
9. This colored solution was placed in a Beckman spectrophotometer and the absorbance was measured at 745 mu.
10. The absorbances were compared with a standard curve. See Plate 1.

Procedure Used for Obtaining the Concentration of Total Reducing Sugars in Corn Extract

1. Five ml. of solution A was pipetted into a test tube to which 5 ml. of Ferricyanide solution was added.
2. The concentrations of total reducing sugars were determined by following procedures 5 through 10 that were used in determining total sugars.

Procedures Used for Determining the Concentration of Fructose

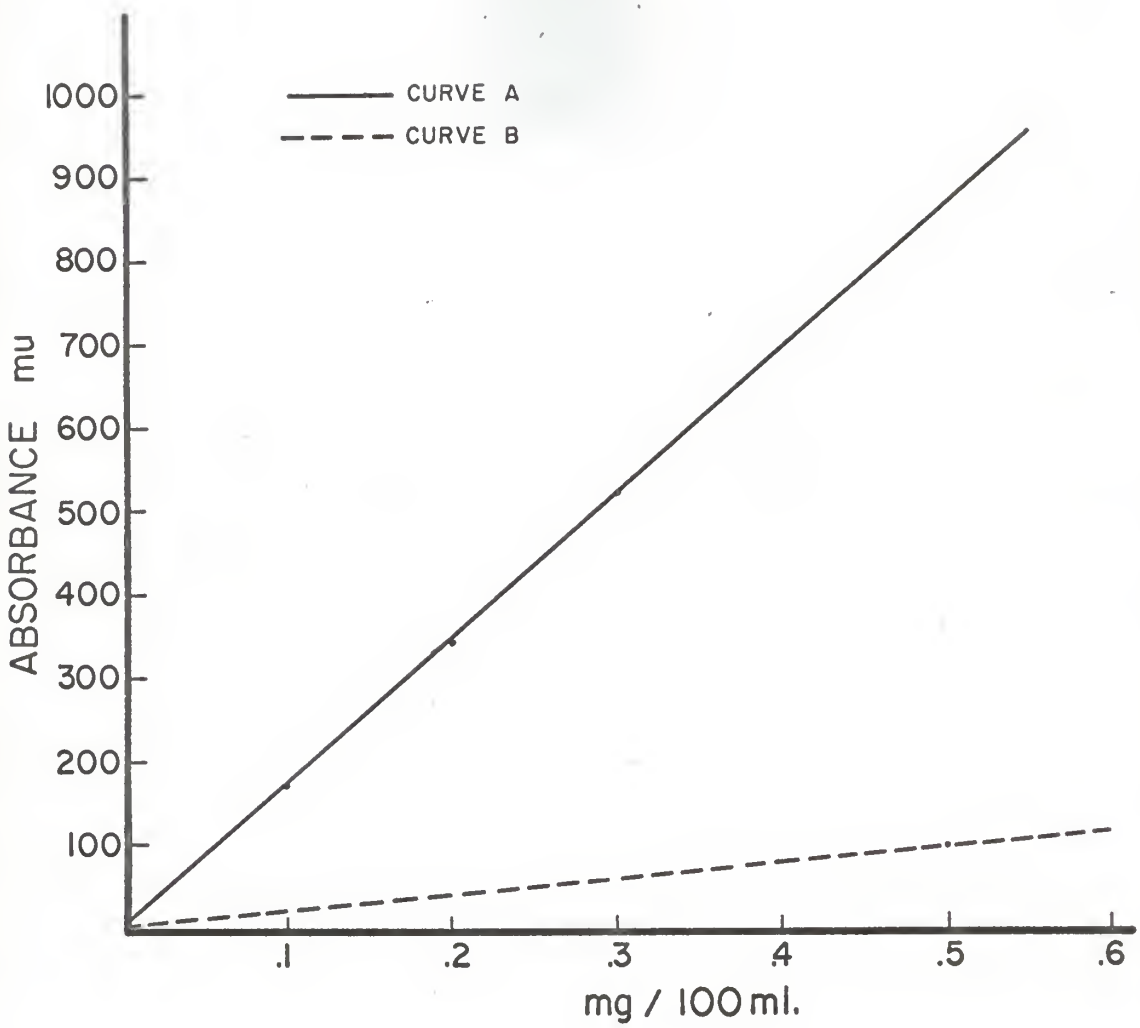
1. Ten ml. of solution A was pipetted into a test tube and 5 ml. of Ferricyanide solution was added.
2. The tube was placed in a water bath which was kept at a constant temperature of 55° C., for 30 minutes. It is very important that the

EXPLANATION OF PLATE I

Standard curve of fructose and glucose in known concentrations at temperatures of 55° and 100° C. as determined with a Beckman Spectrophotometer at a wave length of 745 mu.

Curve A represents fructose and glucose at 100° C. and fructose at 55° C.

Curve B represents glucose at 55° C.


CURVE A
CURVE B
ABSORBANCE mu
1000
900
800
700
600
500
400
300
200
100
.1
.2
.3
.4
.5
.6
mg / 100 ml.

temperature of the bath be kept at 55° C. If it is off 1° C., it will affect the results tremendously.

3. After 30 minutes at 55° C. the solution was rapidly cooled. Then 10 ml of 2N sulfuric acid and 4 ml. of arsenomolybdate solution was added.
4. This green solution was diluted to 100 ml and allowed to stand for at least 15 minutes.
5. The colored solution was placed in the Beckman spectrophotometer with the wave length set at 745 mu and read.
6. The results were compared with the same standard curve as used above. See Plate I.

Procedures Used in Calculating the Percents of Various Types of Sugars Present in Sweet Corn

The percent of total sugar was calculated by placing the absorbance value obtained from a corn sample on the standard curve. Then an imaginary line was drawn down to the abscissa.

The value obtained where the line crossed the abscissa was noted. This was multiplied by a dilution factor of 20,000 for total sugars.

The percent fructose was calculated by taking the value obtained where the line crossed the abscissa times 4,000. The percent total reducing sugar was calculated by taking the value obtained where the line crossed the abscissa times 0.822 times 2,000. The abscissa value was multiplied by 0.882 because 11 to 12 percent of the glucose was oxidized at 55° C. and must be accounted for in determining the amount of fructose.

The percent glucose was calculated by subtracting the percent fructose from the percent total reducing sugar.

The percent sucrose was calculated by subtracting the percent total reducing sugar from the percent total sugars.

Analysis of variance was computed as described by Snedecor (10).

The F test was used to determine significance. To compare 2 treatment means, least significant differences were computed. The F tables are shown in the appendix as tables 12 through 21. The method used to determine the repeatability was that described by Snedecor (10).

EXPERIMENTAL RESULTS

The results from the paper chromatography clearly indicated that only glucose and fructose were present in large enough amounts to give positive tests.

Complete sugar analyses were made when the following factors were varied; the time of day of harvest, cultivar, deepness of cut, maturity level and section of the ear.

Forty-five samples of Sugar King were used in determining the effect of time of day of harvesting on the sugar components. Ears were picked at 6:00 A.M., 12:00 Noon and 4:00 P.M. The results showed no significant difference in percent of total sugars or reducing sugars of ears picked morning, noon or evening. The repeatability for this analysis was around .50 for all the test, which means that twice as many samples should have been run to give reliable results. There was also no significant difference in the ratio of fructose to total reducing sugars among the ears picked at the various times of day. See Table 1.

Table 1. Mean, percent sugar and ratios on fresh weight basis of the Sugar King cultivar harvested at various times of day.

	Total Sugars	Total Reducing Sugars	Fructose	Glucose	Sucrose	Ratio Fructose to total Reducing Sugar	Ratio Total Reducing Sugar to Total Sugar
Morning	4.41	.93	.387	.540	3.48	.414	.210
Noon	4.37	.84	.402	.441	3.53	.478	.191
Evening	4.05	.96	.407	.557	3.08	.424	.212
F Values	.380	.510	.000	1.231	.843	2.80	.286

Mean of the Sugar King cultivar picked at various times of day.

Significant difference in the percentage of sugars occurred between cultivars. The Supersweet cultivar contained almost twice as much total sugar as either the Tendercrisp or the Sugar King cultivars. However, the Supersweet cultivar did not have a significantly greater percent total reducing sugar. The Tendercrisp cultivar had a significantly greater percent total sugar than Sugar King and also had a significantly greater ratio of fructose to total reducing sugars than the other two cultivars as shown in Table 2.

Table 2. Mean, percent sugar and ratios on fresh weight basis of three sweet corn cultivars.

	No. of Samples	Total Sugars	Total Reducing	Fructose	Glucose	Sucrose	Ratio Fructose to Total Reducing Sugars	Ratio Reducing Sugars to Total Sugars
Super Sweet	22	8.62	1.29	.50	.80	7.33	.384	.149
Sugar King	31	3.93	1.12	.45	.67	2.81	.402	.286
Tendercrisp	24	4.98	1.20	.53	.67	3.79	.440	.240
LSD 5%		1.06	NS	NS	NS	1.70	.047	.082

It was also determined that a difference existed in sugars between the two halves of an ear of corn. The butt end had a greater percent total sugars and total reducing sugars. However, there was no apparent difference in

the ratios of total reducing sugars to total sugars and of fructose to total sugars between the two ends of the ear of corn. See Table 3.

Table 3. Mean percent sugars and ratios on a fresh weight basis of butt and tip halves of ears of Tendercrisp sweet corn cultivar.

	Total Sugars	Total Reducing Sugars	Fructose	Ratio Fructose Total Reducing Sugars	Ratio Total Reducing Sugars to Total Sugars
Butt End*	7.67	1.81	.76	.420	.235
Tip End	6.40	1.54	.66	.417	.220

*Averages of five ears.

It was also found that there was a noticeable difference in sugars when the corn kernels were cut shallow. Shallow cuttings consisted of cutting the kernels approximately in the center and using only the top portion. Deep cuttings consisted of cutting the kernels just above the tip cap. When one side of an ear was cut shallow it gave less percent total sugars and total reducing sugars than the other side of the ear which was cut deep. However, there was no apparent difference in ratios of total reducing sugars to total sugars and of fructose to total reducing sugars whether the corn was cut shallow or deep as shown in Table 4.

Table 4. Mean, percent sugars and ratios on a fresh weight basis at different cutting depths of the Super Sweet cultivar.

	Total Sugars	Total Reducing Sugars	Fructose	Ratio Fructose to Total Reducing Sugar	Ratio Total Reducing Sugar to Total Sugars
Cut deep*	8.83	1.31	.53	.404	.148
Cut Shallow	8.42	1.09	.45	.410	.129

*Averages from five ears.

Significant differences were obtained with the various maturity levels for all three cultivars. In all three cultivars the ears in the blister stage had a high total reducing sugar percent which decreased as the ears matured. As the earsreached the doughy stage the decrease in percent reducing sugars began to level off. In all three cultivars the percent total sugars increased with time until a peak was reached at around 10,000 degree hours from silking. Then, total sugars decreased. The effect of maturity on the percent sugar for the Super Sweet, Sugar King, Tendercrisp cultivars respectively are illustrated in (Tables 5, 6 and 7). The percent total sugars then decreased at a decreasing rate. The percent fructose decreased from the blister stage to the doughy stage. In the Sugar King cultivar the decrease in fructose was greater than the decrease in total reducing sugars as the ear matured. The greater decrease in fructose was not so noticeable in the Super Sweet and Tendercrisp cultivar. The percent total sugars of the Super Sweet cultivar did not decrease at the same rate after 10,000 degree hours from silking as occurred with the other two cultivars. The ratio of total reducing sugars to total sugars decreased from the blister to the dough stage in all three cultivars.

Table 5. Sugars in percent and ratios on fresh weight basis in the Super Sweet cultivar at various maturity levels.

Degree Hours in Thousand:	No. of Samples	Total Sugars	Total Reducing Sugars	Fructose	Glucose	Sucrose	Ratio of: Fructose: to Total: Reducing: Sugars	Ratio of Total Reducing Sugars to Total Sugars
7-9	1	6.90	3.15	1.20	1.95	3.75	.381	.457
9-11	8	8.73	1.47	.61	.87	7.25	.415	.168
11-13	5	9.84	.91	.36	.54	8.92	.396	.092
13-18	5	7.90	.60	.24	.41	7.30	.40	.076
18-	3	9.00	.64	.23	.41	8.36	.35	.070
LSD at 5%		1.38	.43	.14	.31	NS	.037	.063

Table 6. Sugar in percent and ratios on fresh weight basis in the Sugar King Cultivar at various maturity levels.

Degree Hours in Thousand:	No. of Samples:	Total Sugars:	Total Reducing Sugars	Fructose:	Glucose:	Sucrose:	Ratio of: Fructose to Total Reducing Sugars	Ratio of Total Reducing Sugars to Total Sugars
7-9	7	4.62	2.00	1.00	1.00	2.27	.500	.433
9-11	7	4.15	.92	.39	.53	3.23	.424	.222
11-13	5	3.33	.71	.28	.42	2.63	.394	.213
13-18	9	2.82	.60	.22	.38	2.22	.367	.213
18-	3	2.80	.55	.18	.37	2.25	.327	.196
LSD at 5%		1.38	.43	.14	.31	NS	.037	.063

Table 7. Sugars in percent and ratios on fresh weight basis in the Tendercrisp Cultivar at various maturity levels.

Degree Hours in Thousands:	No. of Samples:	Total Sugars:	Total Reducing Sugars	Fructose:	Glucose:	Sucrose:	Ratio of: Fructose to Total Reducing Sugars:	Ratio of Total Reducing Sugars to Total Sugars
7-9	1	4.00	2.33	1.20	1.13	1.67	.510	.580
9-11	9	6.72	1.53	.66	.86	5.20	.431	.228
11-13	3	5.40	1.30	.62	.71	4.07	.476	.241
13-18	8	4.20	.70	.26	.44	3.50	.370	.167
18-	3	2.70	.46	.18	.28	2.24	.384	.170
LSD 5%		1.38	.43	.14	.31	NS	.037	.063

Table 8. Repeatability of the maturity experiment

	Total Sugar	Total Reducing Sugar	Fructose	Glucose	Sucrose	Total Reducing Sugar to Total Sugar
Repeatability	.463	.972	.794	.758	.314	.597

DISCUSSION OF RESULTS

The time of day experiment showed that the percent sugars did not vary regardless of the time of day the corn was harvested. However, it must be taken into account that in eastern Kansas there is not a great difference between the day and night temperature during the summer months. Also, it must be taken into account that the results were obtained on a fresh weight basis and not a dry weight basis. There was probably some decrease in the amount of moisture as the day proceeded from morning to evening. Actually, the results which were of most value in this experiment were those involving the ratios of sugars. The data showed that the ratio of total reducing sugars to total sugars did not differ at the various times of day. However, the ratio of fructose to total reducing sugars did change somewhat during the day but not significantly. At noon there appeared to be a higher fructose to total reducing sugars ratio. The repeatability for the ratio in this experiment was .34 which means that three times as many samples should have been run to give good results, (Table 8). This low repeatability factor was due more to the great variation between individual samples than to the error in technique. If there had not been such a great amount of error in sampling, there may have been a significant difference obtained with this ratio.

According to the results, the Super Sweet cultivar had an extremely high percent of total sugars. This was due to the high sucrose content because Super Sweet did not have more than an average percent total reducing sugars. Sucrose did not decrease much as the ear matured, therefore, the Super Sweet cultivar maintained a higher percent total sugar for a longer period of time. The Tendercrisp cultivar had a moderately high sugar content, being a percent more than the Sugar King cultivar. From the results it appeared that the

percent reducing sugars was dependent more on the stage of maturity and temperature during the period of ear development than on the cultivar. The ratio of total reducing sugars to total sugars was considerably lower in the case of the Super Sweet cultivar due to the large percentage of non-reducing sugars. There was no significant difference between the other two cultivars. The Tendercrisp cultivar had a significantly higher ratio of fructose to total reducing sugars than the Super Sweet cultivar and a somewhat larger ratio than the Sugar King cultivar which indicated that fructose made up a greater amount of the total reducing sugars in the Tendercrisp cultivar than in the other two cultivars.

The experiment on the two halves of an ear of corn clearly indicated that the sugars were not distributed uniformly in the ear since the butt end had more sugars than the tip end. The experiment also indicated that no one sugar was translocated at a faster rate to a particular area than other sugars since the ratios of fructose to total reducing sugars and total reducing sugars to total sugar did not differ between the butt and tip end of the ear of corn.

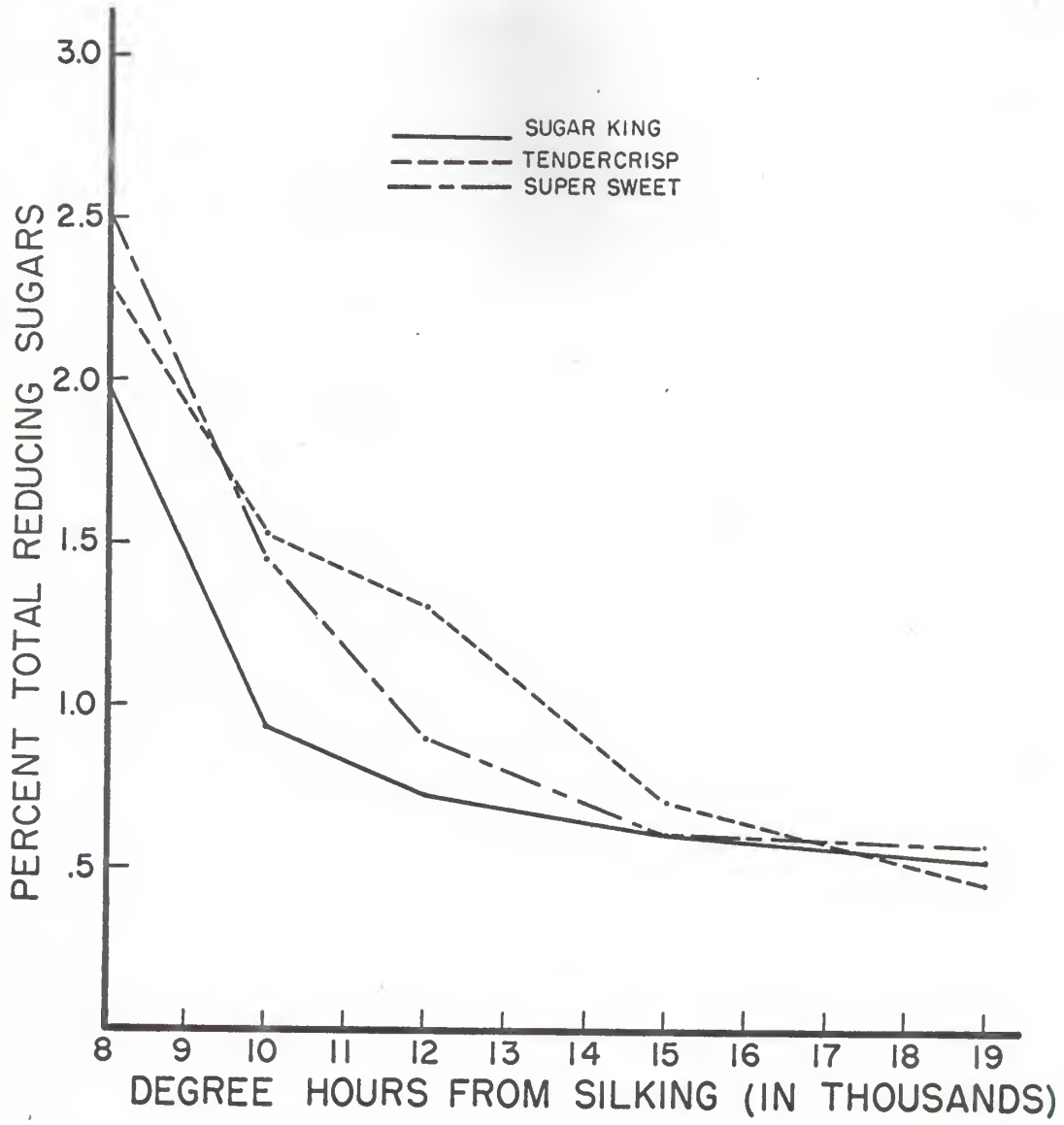
The experiment on depth of cutting showed that there was a higher percent of both total sugars and total reducing sugars near the cob. The portion near the cob had the same ratio of types of sugars as the outer portions.

The results of the stage of maturity experiment agreed with those obtained by Appleman (2) and Magoon et al (8), indicating the percent reducing sugar decreased as the ear matured (Plate II). However, the results indicated that the percent total reducing sugars were somewhat less than those of the early experimenters. This could be due partially to difference in cultivars or growing conditions.

Fructose made up about 40 percent of the total reducing sugars. According to early researchers, the time when the corn was the sweetest was at the time of highest sucrose content and not when the percent total sugars was the highest.

EXPLANATION OF PLATE II

Percent total reducing sugars on a fresh weight basis of three sweet corn cultivars as determined by degree hours from silking.


SUGAR KING
TENDERCRISP
SUPER SWEET
PERCENT TOTAL REDUCING SUGARS
3.0
2.5
2.0
1.5
1.0
.5
8
9
10
11
12
13
14
15
16
17
18
19
DEGREE HOURS FROM SILKING (IN THOUSANDS)

They believed sucrose was much sweeter than the reducing sugars. This would be true if the total reducing sugars were made up of glucose since glucose is only three-fourths as sweet as sucrose. However, fructose is 1½ to 1¾ times as sweet as sucrose and taking into account that fructose made up 40 percent of the total reducing sugars, then there was very little if any difference in the sweetness of sucrose and total reducing sugars. Therefore, the corn was the sweetest when the percent total sugars were the highest. However, this may not be the proper time to pick the corn since other factors such as the starch content and moisture content should be considered.

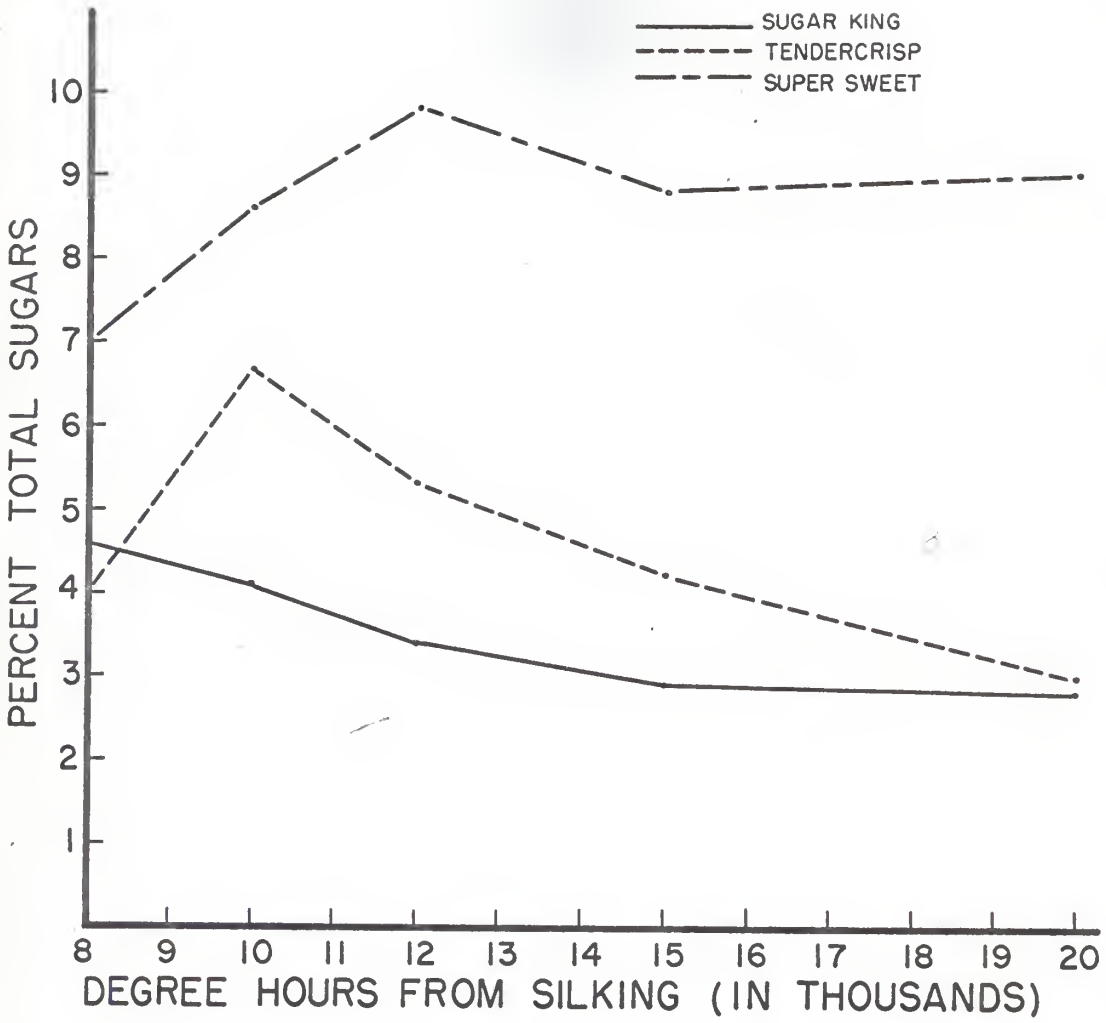
The percent of fructose decreased at a faster rate than the percent total reducing sugars as the ear matured in the Sugar King cultivar (Plates IV, V, VI and VII). In the Super Sweet and Tendercrisp cultivars the faster decrease in fructose was not so noticeable. It must be considered that when the percent fructose of the total reducing sugars was decreased 20 percent, the sweetness of the total reducing sugars was decreased 40 percent since fructose is twice as sweet as glucose. However, the threshold of sweetness for sugar is 0.4 percent which indicated only at the early three maturity levels that the fructose concentrations were high enough to be tasted. Only in the first two maturity levels could the ratio of fructose to total reducing sugars be an important factor in determining the flavor of sweet corn.

The experiment on the effects of stage of maturity on the percent total sugar gave results which were in agreement with those obtained by Magoon and Culpepper (8). The percent total sugars first increased until the ear reached around the 10,000 degree hour level and then the total sugars decreased at a steady rate corresponding to a steady increase in starch. Plate III.

The percent sucrose did not significantly change with the change in the maturity level. Plate VIII. This indicated that sucrose was being translocated

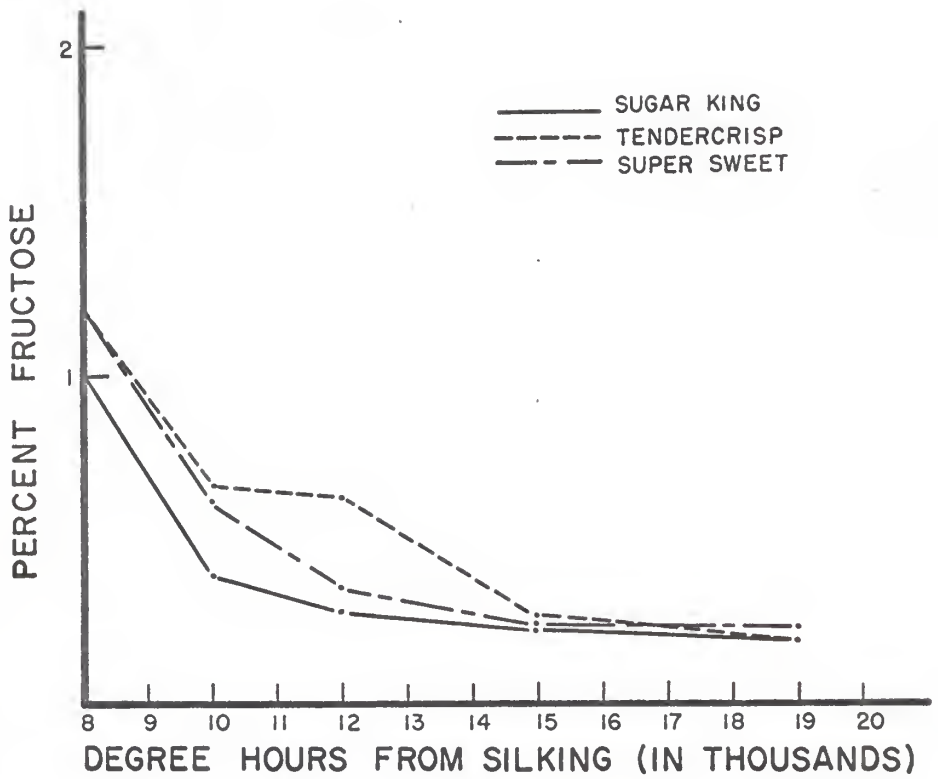
EXPLANATION OF PLATE III

Percent total sugars on a fresh weight basis of three sweet corn cultivars as determined by the degree hours from silking.


SUGAR KING
TENDERCRISP
SUPER SWEET
PERCENT TOTAL SUGARS
10
9
8
7
6
5
4
3
2
1
8
9
10
11
12
13
14
15
16
17
18
19
20
DEGREE HOURS FROM SILKING (IN THOUSANDS)

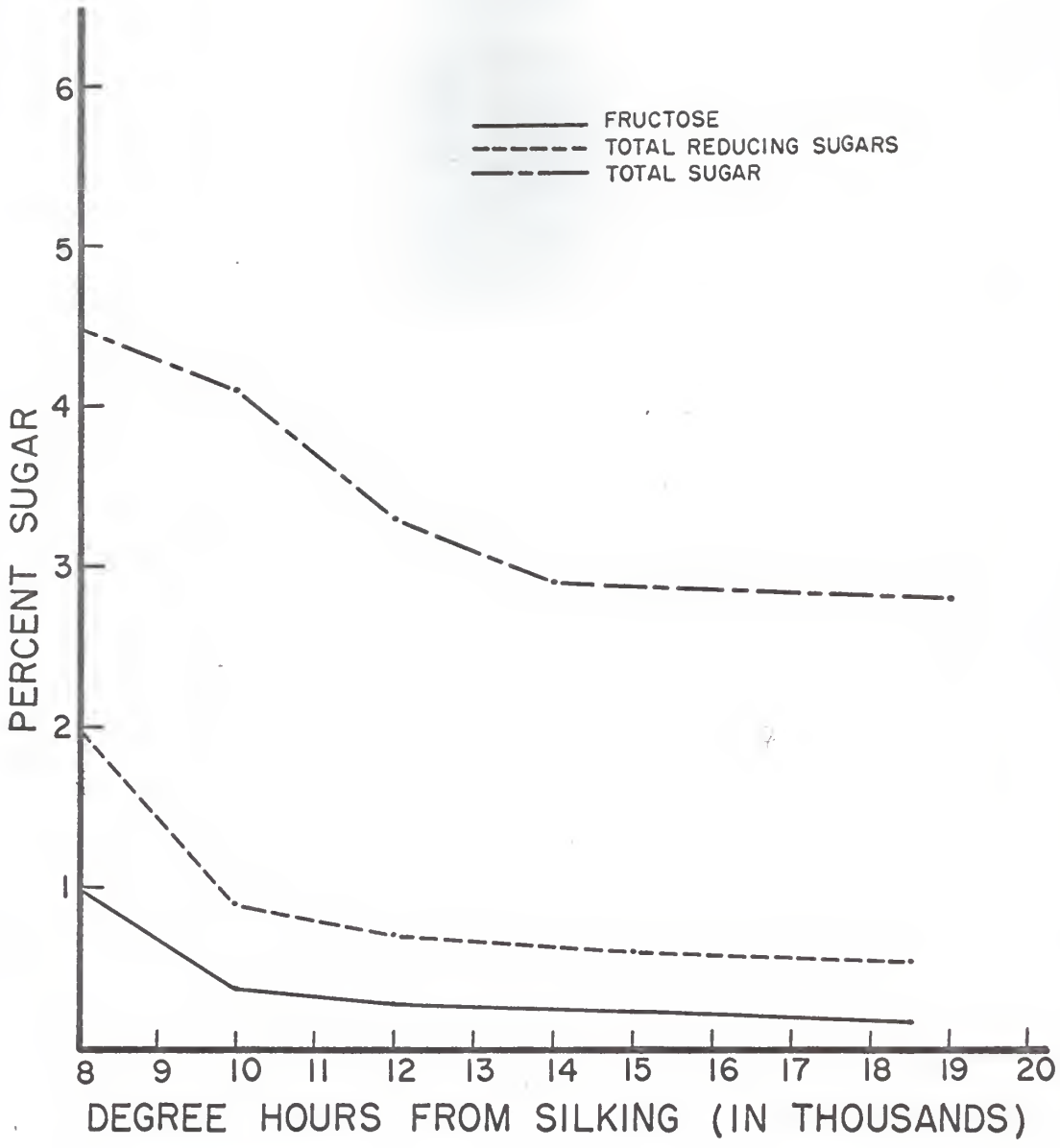
EXPLANATION OF PLATE IV

Percent fructose on a fresh weight basis of three sweet corn cultivars as determined by the degree hours from silking.


SUGAR KING
TENDERCRISP
SUPER SWEET
PERCENT FRUCTOSE
2
1
8
9
10
11
12
13
14
15
16
17
18
19
20
DEGREE HOURS FROM SILKING (IN THOUSANDS)

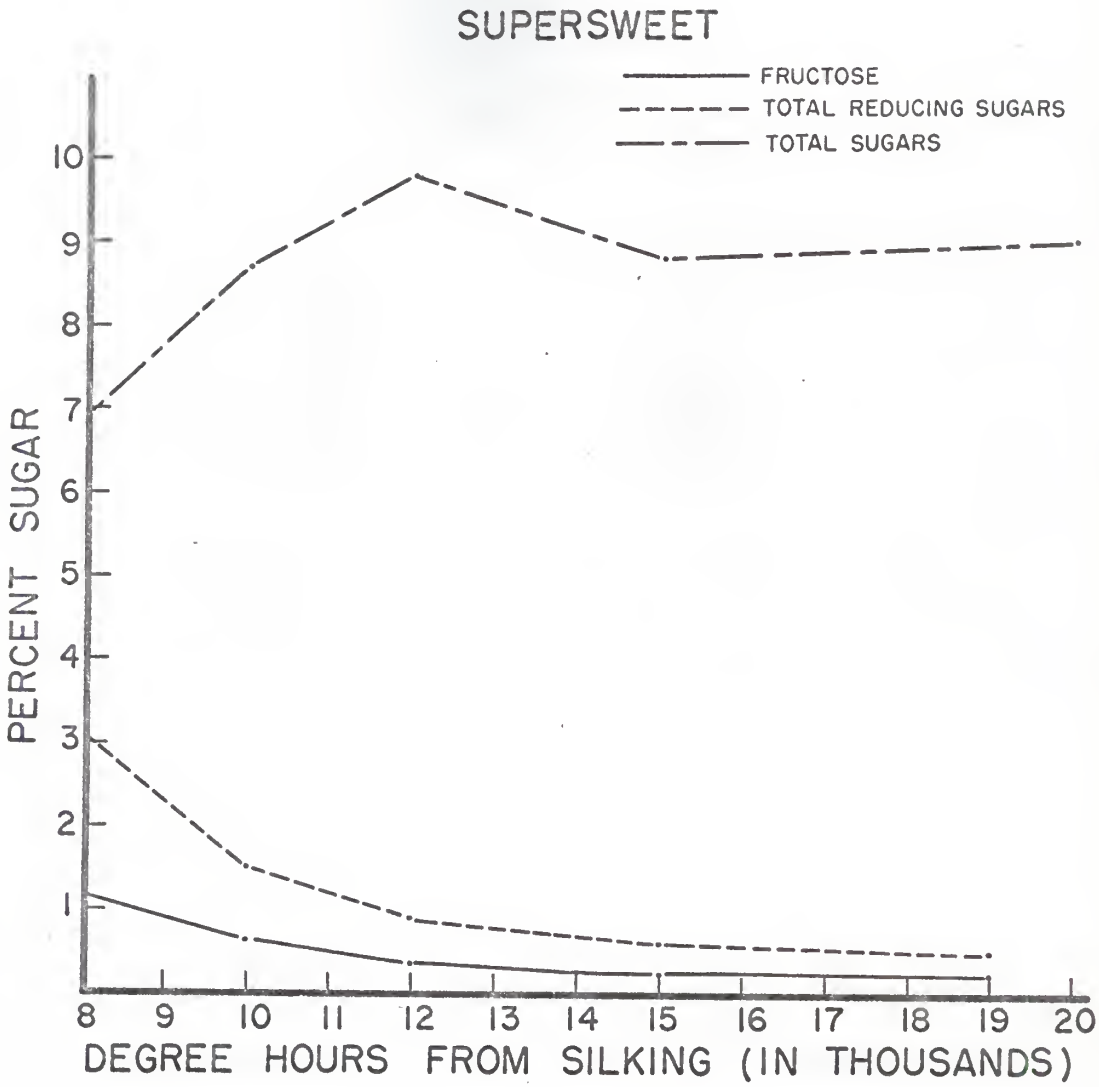
EXPLANATION OF PLATE V

Percent sugars on a fresh weight basis of the Sugar King cultivar determined by degree hours from silking for total sugars, total reducing sugars and fructose.


FRUCTOSE
TOTAL REDUCING SUGARS
TOTAL SUGAR
PERCENT SUGAR
6
5
4
3
2
1
8
9
10
11
12
13
14
15
16
17
18
19
20
DEGREE HOURS FROM SILKING (IN THOUSANDS)

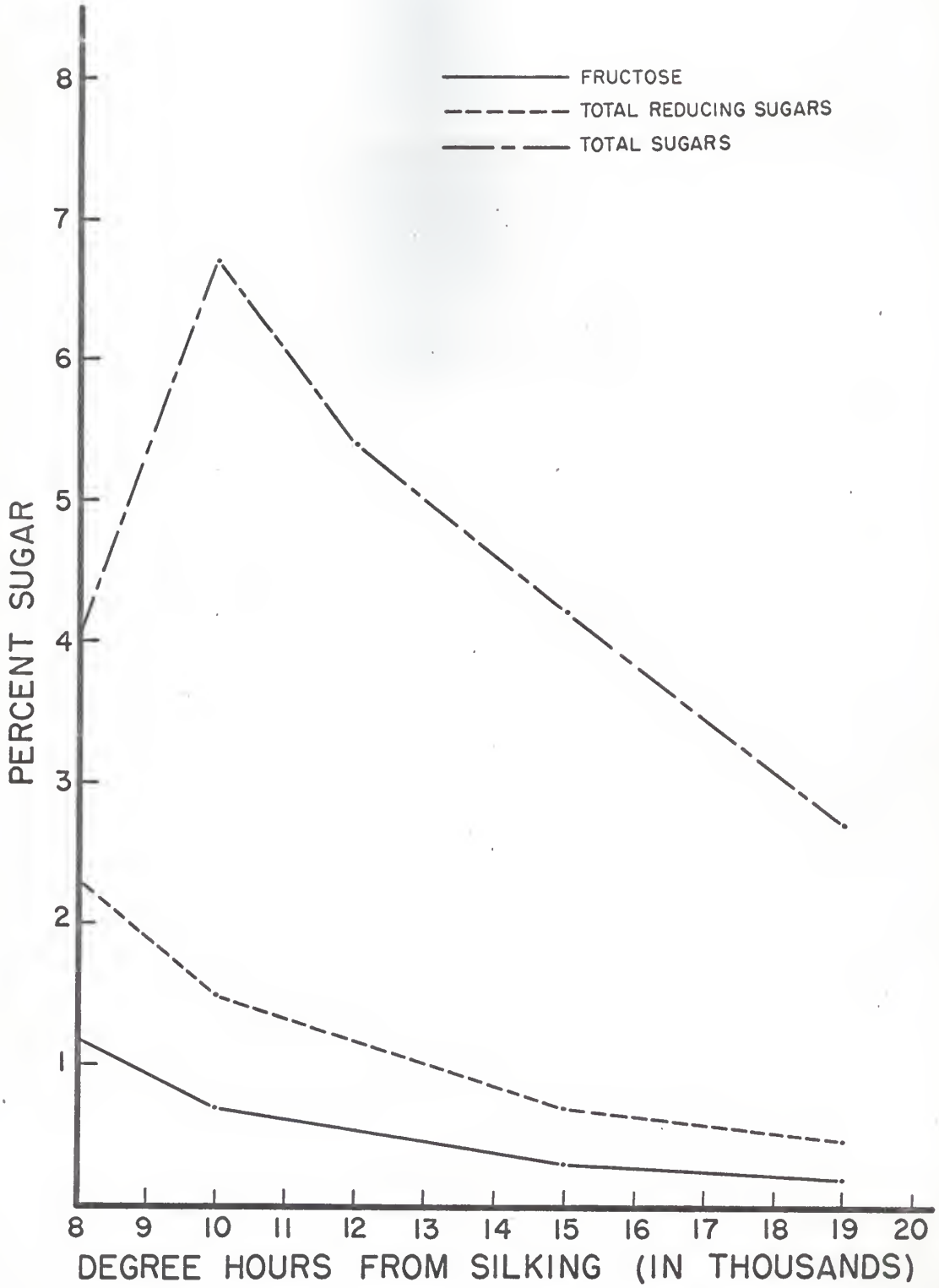
EXPLANATION OF PLATE VI

Percent sugars on a fresh weight basis of the Super Sweet Cultivar determined by degree hours from silking for total sugars, total reducing sugars and fructose.


SUPERSWEET
FRUCTOSE
TOTAL REDUCING SUGARS
TOTAL SUGARS
PERCENT SUGAR
10
9
8
7
6
5
4
3
2
1
8
9
10
11
12
13
14
15
16
17
18
19
20
DEGREE HOURS FROM SILKING (IN THOUSANDS)

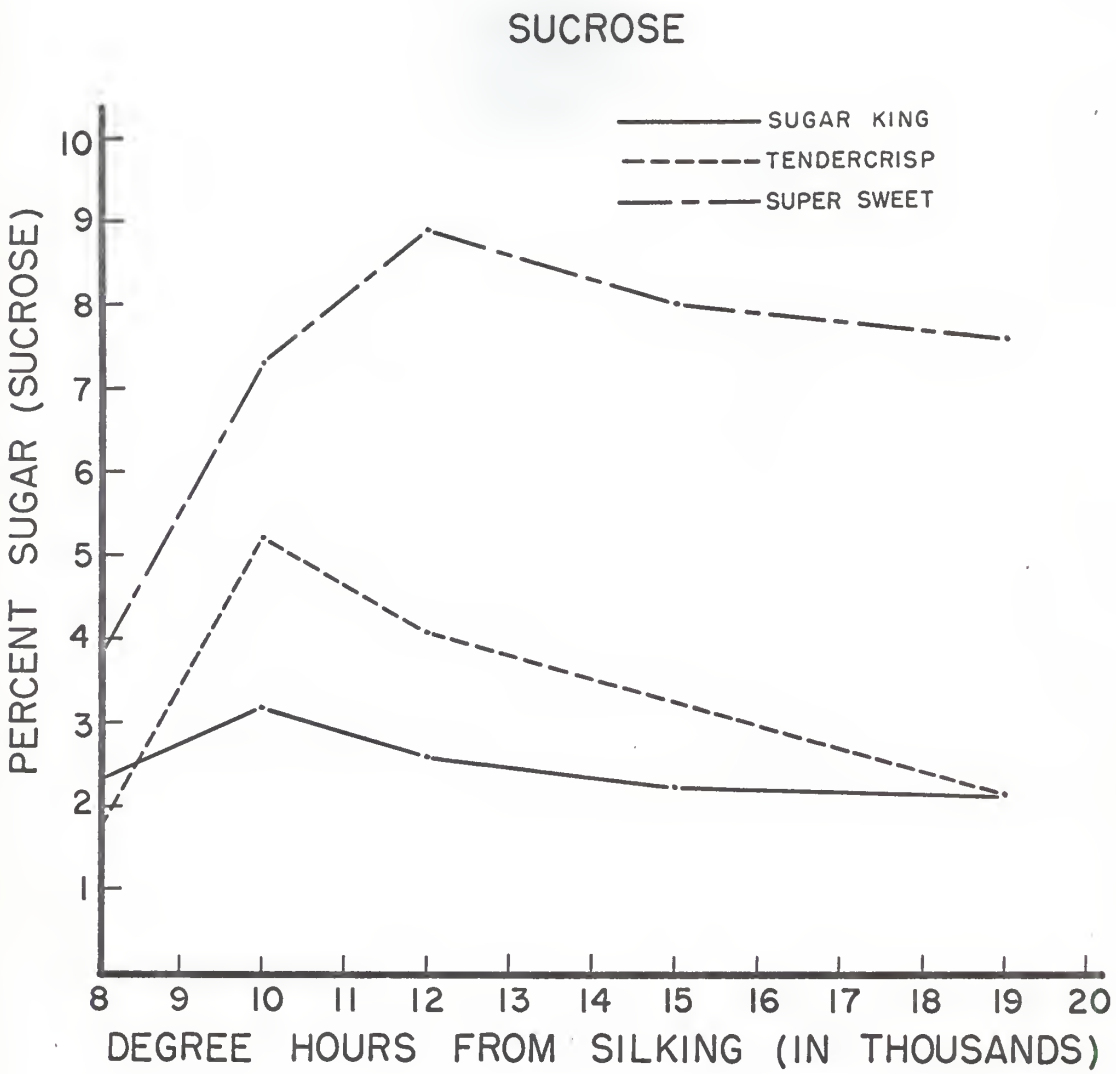
EXPLANATION OF PLATE VII

Percent sugars on a fresh weight basis of the Tendercrisp cultivar determined by degree hours from silking for total sugars, total reducing sugars and fructose.


FRUCTOSE
TOTAL REDUCING SUGARS
TOTAL SUGARS
PERCENT SUGAR
1
2
3
4
5
6
7
8
8 9 10 11 12 13 14 15 16 17 18 19 20
DEGREE HOURS FROM SILKING (IN THOUSANDS)

EXPLANATION OF PLATE VIII

Percent sucrose on a fresh weight basis of three sweet corn cultivars as determined by degree hours from silking.


SUCROSE
SUGAR KING
TENDERCRISP
SUPER SWEET
PERCENT SUGAR (SUCROSE)
10
9
8
7
6
5
4
3
2
1
8
9
10
11
12
13
14
15
16
17
18
19
20
DEGREE HOURS FROM SILKING (IN THOUSANDS)

into the ear about as fast as it was being converted into starch. The percent sucrose was dependent on genetic make-up of the ear since the Super Sweet cultivar had twice as much sucrose as the Tendercrisp or Sugar King cultivar. Sucrose made up the largest portion of the total sugars except at the first maturity level. This agreed with the results of Appleman (2).

SUMMARY

Sugar concentretions of sweet corn are influenced by varying certain conditions.

1. When corn was harvested at various times of day, the percent sugars did not vary significantly.
2. Of the three cultivars studied, Super Sweet had an extremely high sucrose content. The other two cultivars were average in percent sucrose.
3. The Super Sweet cultivar retained a high percent total sugar for a longer period of time than the other two cultivars.
4. The butt end of an ear of corn of the Super Sweet cultivar had a higher percent total sugars than the tip end. The sugar ratios were constant for both ends of the ear.
5. There was a higher percent total sugars near the cob. The portion near the cob seemed to have the same ratio of types of sugars as the outer portions.
6. The percent reducing sugars decreased as the ear matured.
7. Fructose made up around 40 percent of the total reducing sugars.
8. The percent of fructose decreased at a faster rate than the percent total reducing sugars asthe ear matured.

9. The percent total sugars first increased until the ear approached the 10,000 degree hour level and then decreased at a steady rate.
10. The percent sucrose did not significantly change with the change in the maturity level.

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APPENDIX

Table 9. Analysis of variance for effects of time of day and degree hours on total sugar content of the Sugar King cultivar.

Factors	df	Ss	Ms	F
Time of Day	2	.239	.1195	.380
Degree Hours	2	.304	.152	.491
Error	4	1.238	.3095	

Table 10. Analysis of variance for effect of time of day and degree hours on total reducing sugar content of the Sugar King cultivar.

Factors	df	Ss	Ms	F
Time of Day	2	.025	.0125	.510
Degree hours	2	.099	.0495	2.02
Error	4	.098	.0245	

Table 11. Analysis of variance for effect of time of day and degree hours on fructose content of the Sugar King cultivar.

Factors	df	Ss	Ms	F
Time of Day	2	.000	.000	.000
Degree hours	2	.027	.0135	2.84
Error	4	.019	.00475	

Table 12. Analysis of variance for effect of time of day and degree hours on glucose content of the Sugar King cultivar.

Factors	df	Ss	Ms	F
Time of day	2	.024	.012	1.231
Degree Hours	2	.021	.010	1.077
Error	4	.039	.00975	

Table 13. Analysis of variance for effect of time of day and degree hours on sucrose content of the Sugar King cultivar.

Factor	df	Ss	Ms	F
Time of day	2	.359	.1795	.843
Degree Hours	2	.160	.080	.375
Error	4	.851	.213	

Table 14. Analysis of variance for effect of time of day and degree hours on the ratio of fructose to total reducing sugars.

Factors	df	Ss	Ms	F
Time of day	2	.007	.0035	2.80
Degree hours	2	.002	.001	.80
Error	4	.005	.00125	

Table 15. Analysis of variance for effect of time of day and degree hours on the ratio of total reducing sugars to total sugars in the Sugar King cultivar.

Factors	df	Ss	Ms	F
Time of day	2	.001	.0005	.286
Degree hours	2	.010	.005	2.86
Error	4	.007	.00175	

Table 16. Analysis of variance for the effect of stage of maturity and cultivar on the total sugar content of sweet corn samples.

Factor	df	Ss	Ms	F
Cultivar	2	67.342	33.671	81.8**
Maturity	4	15.282	3.82	9.28**
Error	8	1.646	.4115	

Table 17. Analysis of variance for the effect of stage of maturity and cultivar on the total reducing sugar content of sweet corn samples.

Factor	df	Ss	Ms	F
Cultivar	2	.436	.218	2.508
Maturity	4	7.436	1.859	21.39**
Error	8	.695	.0869	

Table 18. Analysis of variance for the effect of stage of maturity and cultivar on the fructose content of sweet corn samples.

Factor	df	Ss	Ms	F
Cultivar	2	.0654	.0327	3.80
Maturity	4	1.709	.4272	49.68**
Error	8	.0686	.0086	

Table 19. Analysis of variance for the effect of stage of maturity and cultivar on the sucrose content of sweet corn samples.

Factor	df	Ss	Ms	F
Cultivar	2	60.129	30.064	22.154**
Maturity	4	14.085	3.52	2.594
Error	8	10.857	1.357	

Table 20. Analysis of variance for the effect of stage of maturity and cultivar on the ratio of fructose to total reducing sugars.

Factors	df	Ss	Ms	F
Cultivar	2	.012	.006	9.60**
Maturity	4	.029	.00725	11.60**
Error	8	.005	.000625	

Table 21. Analysis of variance for effect of stage of maturity and cultivar on the ratio of total reducing sugars to total sugars in the sweet corn samples.

Factor	df	Ss	Ms	F
Cultivar	2	4.36	.218	2.508
Maturity	4	7.436	1.859	21.39**
Error	8	.695	.0869	

SUGAR COMPONENTS OF SWEET CORN CULTIVARS AS INFLUENCED BY MATURITY PATTERNS

By

JAMES FRANKLIN KIENTZ

B.S., Kansas State University, 1964

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1965

The sweet corn ear undergoes many changes in chemical composition as it matures. One of the major changes is the change in sugar composition. The objectives of this study were: (a) to determine what sugars were present; (b) to determine how the percent of the various sugar components change as the ear matures; (c) to determine what difference in percent sugar components occur in three different cultivars and (d) to determine the effect of the time of day of harvest on the percent sugar components.

Three sweet corn cultivars and three dates of planting furnished the 170 samples used in this study. Each of the three cultivars; Sugar King, Tendercrisp, and Super Sweet were planted on May 4, May 22, and June 2. The ears were picked at 10 days, 15 days and 23 days after the first silks appeared. Since the temperature varied considerably when the ears were maturing, the samples were categorized according to the number of degree hours from silking. The sugars were extracted from the corn kernels in 95% ethanol. The types of sugars were determined by using a paper chromatogram. The percent of the various sugars present was determined colormetrically by using aklaline ferricyanide solution as an oxidizing agent and Nelson's arsenomolybdate reagent as a coloring reagent. A portion of the solution of sweet corn sugars was hydrolyzed with HCl and then tested for sugars to determine the percent total sugars present. The percent fructose was determined by heating the mixture of the ferricyanide and the sweet corn sugar solutions at 55° C. for 30 minutes instead of heating at 100° C. for 10 minutes as was done in determining the percent total sugars and total reducing sugars.

The results from the paper chromatogram showed that glucose and fructose were the only reducing sugars present in large enough amounts to give positive tests. Significant differences in percent of total sugars or reducing sugars of ears picked in the morning, noon or evening did not occur. The ears picked

at noon had a larger ratio of fructose to total reducing sugars than either the morning or evening samples. The Super Sweet cultivar contained almost twice as much total sugar as either the Tendercrisp or the Sugar King cultivars. The difference in total sugars between cultivars can be attributed to the difference in sucrose content and not its total reducing sugars. The butt end of the sweet corn ear had a greater percent total sugars and total reducing sugars than the tip end. When sweet corn kernels were cut shallow, they contained a smaller percent total sugars and total reducing sugars than when the kernels were cut deep. In all three cultivars the ears in the blister stage had a high total reducing sugar percent which decreased as the ears matured. In all three cultivars the percent total sugars increased with time until a peak was reached at around 10,000 degree hours from silking, then decreased steadily. The percent total sugars of the Super Sweet cultivar did not decrease nearly as fast as the other two cultivars after 10,000 degree hours from silking. In the Sugar King cultivar the decrease in fructose was greater than the decrease in total reducing sugars as the ears matured. About forty percent of the total reducing sugars was fructose. The ratio of total reducing sugar to total sugars decreased from the blister to the doughy stage.