Literature Cited

(1) Assoc. Vitamin Chemists, "Methods of Vitamin Assay," 2nd ed., pp. 52–63, Interscience, New York, 1951.
(2) Bessey, O. A., Lowry, O. H., Brock, M. J., *J. Biol. Chem.* **168,** 197–205 (1947).
(3) Burger, M., Hein, L. W., Teply, L. J., Derse, P. H., Krieger, C. H., J. Agr. Food Chem. **4,** 418–25 (1956).
(4) Guerrant, N. B., O'Hara, M. B., *Food Technol.* **7,** 473–7 (1953).
(5) Guerrant, N. B., Vavich, M. G., Fardig, O. B., Ellenberger, H. A., *Ind. Eng. Chem.* **39,** 1000–7 (1947).
(6) Hall, A. P., Moore, J. G., Gunning, B., Cook, B. B., J. Agr. Food Chem. **6,** 377–82 (1958).
(7) Harris, R. S., von Loesecke, H., "Nutritional Evaluation of Food Processing," Chap. 3, Wiley, New York, 1960.
(8) Ives, M., Strong, F. M., *Arch. Biochem.* **9,** 251–8 (1946).
(9) Shaffert, R. R., Kingsley, G. R., *J. Biol. Chem.* **212,** 59–68 (1955).
(10) Teply, L. J., Derse, P. H., *J. Am. Dietet. Assoc.* **34,** 836–40 (1958).
(11) Tressler, D. K., Evers, C. F., "Preservation of Foods," 3rd ed., pp. 411–13, Avi Publishing Co., New York, 1951.
(12) Yamaguchi, M., MacGillivray, J. H., Howard, F. D., Simone, M., Sterling, C., *Food Research* **19,** 617–26 (1954).
(13) Zook, E. G., MacArthur, M. J., Toepfer, E. W., U. S. Dept. Agr., Agr. Handbook **97** (1956).

Received for review October 30, 1959. Accepted December 27, 1960.

STORAGE EFFECTS ON WINTER SQUASHES

Associations between the Sugar and Starch Content of and the Degree of Preference for Winter Squashes

SUSAN B. MERROW and RICHARD J. HOPP
University of Vermont, Burlington, Vt.

Six varieties of winter squashes were studied to determine the differences between and effect of storage on the total sugar and starch content and the extent to which varietal differences and changes in these constituents were associated with preference. Increases in total sugar content resulted in varietal differences during storage. Varietal differences in starch content varied depending on the extent and rate of decrease in starch during storage. While the major sugar accumulation occurred within the first 5 weeks of storage with little or no change thereafter, starch decreased in an exponential fashion throughout storage. The sugar-starch ratio was approximately the same for all six varieties at harvest, and increased to approximately 1.00 after 5 weeks of storage. Subsequent increases in the ratio, due primarily to continuous decrease in starch, differed between varieties. Varietal differences in acceptability appear to be related to the sugar-starch ratio and total solids content as well as the absolute amount of total sugar and starch.

For many years it has been an accepted practice to store winter squashes for a period after harvest, preliminary to marketing. This practice is based not only on economic considerations, but also on the assumption that due to certain chemical changes, the eating quality of winter squashes is improved during this storage. This study was made to provide additional data on the effect of storage on, and the differences between, the total sugar and starch content of six varieties of winter squashes and to determine the extent to which varietal differences and changes in these constituents were associated with changes in preference.

Since 1905, when LeClerc du Sablon reported a decrease in total solids and starch content and an increase in total sugar content of fruits of cucurbits during storage (*13*), various reports have appeared in the literature to confirm these findings.

Probably, the most elaborate study to date on the composition of Cucurbita fruits was conducted by Culpepper and Moon (*2*). Thirty-six varieties of pumpkin and winter squashes were grown from 1 to 4 years. Chemical analyses were conducted at different stages of development and after different periods of storage and the findings were analyzed statistically to determine differences between and among varieties and the effect of storage on the constituent content. Varietal differences in total solids and total starch at harvest were apparent as were the differences in the rates of decrease during storage. On the average, two thirds of the decrease in total solids and one half of the decrease in total starch occurred in the first 4 weeks of storage. The major increase in total sugar occurred, on the average, during the first 4 weeks of storage, but this average is not too meaningful since there were wide varietal differences at harvest and the rate of increase varied considerably between varieties. Varieties relatively high in total starch at harvest tended to be the varieties relatively high in sugar following storage.

These authors also found that varietal differences in total sugar, starch, and solids content at harvest and during storage were related to the flavor, consistency, and appearance of many of the squashes. Thus both variety and length of storage were important factors in selecting winter squashes for a specific culinary use.

Cummings and Stone (*4*) found that with Blue Hubbard squashes edibility tests, substantiated by chemical analyses, showed that specimens of good quality contain more carbohydrates and less water than do others of poor quality. Yeager and Latzke (*16*) found high positive correlation coefficients between dry matter and texture, dry matter and high quality, total sugars and high quality, and total sugar and sweetness in Buttercup squashes.

This paper presents the findings of comparisons between the sugar and starch content of six varieties of winter squashes, the changes during 25 weeks of storage, the relative preference for these six varieties, and associations between and among the relative preference

Table I. Mean Values[a] and Significance ($P = 0.01$) of Varietal Differences[b] in Sugar and Starch of Winter Squashes

Sugar

	Harvest						*15 Weeks Storage*					
Total solids[c]	BC[d] 30.6	SM 25.9	SB 25.2	BB 24.1	BH 23.2	BN 19.2	BC 22.8	BB 21.8	SB 21.3	SM 20.4	BN 18.4	BH 12.6
Sugar, dry basis	BN 16.40	SB 15.56	BH 14.31	BC 12.81	SM 12.51	BB 12.20	BH 52.72	SM 51.94	SB 48.67	BC 48.64	BN 45.10	BB 31.11
Fresh basis	SB 3.89	BC 3.78	BH 3.33	SM 3.24	BN 3.14	BB 2.92	BC 11.08	SM 10.37	SB 10.37	BN 8.27	BB 6.77	BH 6.65
Fresh basis adjusted	SB 3.89	BC 3.78	BH 3.33	SM 3.24	BN 3.14	BB 2.92	BC 9.50	SB 9.17	SM 9.16	BN 6.60	BH 5.99	BB 5.51

	5 Weeks Storage						*20 Weeks Storage*					
Total solids[c]	BC 28.4	BB 26.9	SB 22.9	SM 22.6	BN 20.0	BH 17.9	BB 21.9	BC 21.6	SB 20.8	SM 16.2	BN 13.6	BH 11.8
Sugar, dry basis	BH 39.68	SM 38.84	BC 38.44	BN 30.92	SB 30.26	BB 25.05	SM 58.15	BN 57.88	SB 51.78	BH 50.51	BC 48.40	BB 33.02
Fresh basis	BC 10.88	SM 8.50	BH 7.05	SB 6.90	BB 6.70	BN 6.19	SB 10.74	BC 10.33	SM 9.43	BN 7.86	BB 7.02	BH 5.85
Fresh basis adjusted	BC 9.78	SM 7.85	BH 6.50	SB 6.45	BB 5.92	BN 5.47	SB 9.31	BC 8.54	SM 8.18	BN 6.01	BB 5.68	BH 5.16

	10 Weeks Storage						*25 Weeks Storage*					
Total solids[c]	BC 30.0	SB 22.7	BB 22.2	SM 22.1	BN 18.2	BH 13.7	BC 21.7	BB 20.8	SB 19.4	SM 16.4	BN 14.8	BH 12.6
Sugar, dry basis	BH 52.10	SM 46.36	SB 44.44	BN 38.13	BC 35.68	BB 30.10	BN 59.42	SM 59.00	SB 55.53	BH 52.11	BC 49.98	BB 35.70
Fresh basis	BC 10.66	SB 10.10	SM 9.94	BH 7.08	BN 6.91	BB 6.55	BC 10.85	SB 10.74	SM 9.72	BN 8.78	BB 7.41	BH 6.50
Fresh basis adjusted	BC 9.19	SB 9.12	SM 9.02	BH 6.48	BN 5.79	BB 5.56	SB 9.18	BC 8.89	SM 8.22	BN 6.42	BB 5.88	BH 5.64

Starch

	Harvest						*15 Weeks Storage*					
Starch, dry basis	BC 61.08	SB 58.62	SM 56.26	BN 54.45	BH 50.80	BB 49.97	BN 19.45	BB 18.04	SB 15.44	BC 13.44	SM 10.29	BH 0.71
Fresh basis	BC 18.54	SB 14.69	SM 14.60	BB 11.98	BH 11.24	BN 10.37	BB 3.92	BN 3.56	SB 3.32	BC 3.15	SM 2.33	BH 0.11
Fresh basis adjusted	BC 18.54	SB 14.69	SM 14.60	BB 11.98	BH 11.24	BN 10.37	BB 3.20	SB 2.94	BN 2.83	BC 2.70	SM 2.07	BH 0.10

	5 Weeks Storage						*20 Weeks Storage*					
Starch, dry basis	SB 41.05	BN 40.06	BC 37.92	SM 31.67	BB 31.58	BH 25.82	SB 13.48	BB 11.54	BC 9.86	BN 9.07	SM 3.25	BH 2.22
Fresh basis	BC 10.91	SB 9.41	BB 8.50	BN 8.00	SM 7.40	BH 4.54	BB 2.94	SB 2.82	BC 2.39	BN 1.24	SM 0.59	BH 0.22
Fresh basis adjusted	BC 9.79	SB 8.79	BB 7.50	BN 7.08	SM 6.83	BH 4.19	SB 2.44	BB 2.36	BC 1.96	BN 0.94	SM 0.51	BH 0.19

	10 Weeks Storage						*25 Weeks Storage*					
Starch, dry basis	BC 36.74	BN 27.56	SB 25.27	SM 24.30	BB 18.05	BH 8.29	BB 14.13	BC 9.42	SB 8.18	BN 3.05	SM 2.73	BH 2.05
Fresh basis	BC 11.09	SB 5.72	SM 5.60	BN 5.03	BB 4.32	BH 1.21	BB 2.99	BC 2.08	SB 1.60	SM 0.52	BN 0.44	BH 0.25
Fresh basis adjusted	BC 9.57	SB 5.16	SM 5.08	BN 4.23	BB 3.66	BH 1.11	BB 2.37	BC 1.68	SB 1.37	SM 0.43	BN 0.32	BH 0.22

[a] Mean of four replications, expressed as per cent.
[b] Any two means *not underscored* by the same line are *significantly different*. Any two means *underscored* by the same line are *not significantly different*.
[c] Same percentages hold also for starch.
[d] BB = Baby Blue. BC = Buttercup. BH = Blue Hubbard. BN = Butternut. SB = Silver Bell. SM = Sweet Meat.

Table II. Mean Values[a] and Significance ($P = 0.01$) of Changes[b] in Sugar and Starch of Winter Squashes During Storage

Sugar

	Baby Blue						*Blue Hubbard*					
Total solids[c]	(5)[d] 26.9	(0) 24.1	(10) 22.2	(20) 21.9	(15) 21.8	(25) 20.8	(0) 23.2	(5) 17.9	(10) 13.7	(15) 12.6	(25) 12.6	(20) 11.8
Sugar, dry basis	(0) 12.20	(5) 25.05	(10) 30.10	(15) 31.11	(20) 33.02	(25) 35.70	(0) 14.31	(5) 39.68	(20) 50.51	(10) 52.10	(25) 52.11	(15) 52.72
Fresh basis	(0) 2.92	(10) 6.55	(5) 6.70	(15) 6.77	(20) 7.02	(25) 7.41	(0) 3.33	(20) 5.85	(25) 6.50	(15) 6.65	(5) 7.05	(10) 7.08
Fresh basis adjusted	(0) 2.92	(15) 5.51	(10) 5.56	(20) 5.68	(25) 5.88	(5) 5.92	(0) 3.33	(20) 5.16	(25) 5.64	(15) 5.99	(10) 6.48	(5) 6.50

	Buttercup						*Silver Bell*					
Total solids[c]	(0) 30.6	(10) 30.0	(5) 28.4	(15) 22.8	(25) 21.7	(20) 21.6	(0) 25.2	(5) 22.9	(10) 22.7	(15) 21.3	(20) 20.8	(25) 19.4
Sugar, dry basis	(0) 12.81	(10) 35.68	(5) 38.44	(20) 48.40	(15) 48.64	(25) 49.98	(0) 15.56	(5) 30.26	(10) 44.44	(15) 48.67	(20) 51.78	(25) 55.53
Fresh basis	(0) 3.78	(20) 10.33	(10) 10.66	(25) 10.85	(5) 10.88	(15) 11.08	(0) 3.89	(5) 6.90	(10) 10.10	(15) 10.37	(20) 10.74	(25) 10.74
Fresh basis adjusted	(0) 3.78	(20) 8.54	(25) 8.89	(10) 9.19	(15) 9.50	(5) 9.78	(0) 3.89	(5) 6.45	(10) 9.12	(15) 9.17	(25) 9.18	(20) 9.31

	Butternut						*Sweet Meat*					
Total solids[c]	(5) 20.0	(0) 19.2	(15) 18.4	(10) 18.2	(25) 14.8	(20) 13.6	(0) 25.9	(5) 22.6	(10) 22.1	(15) 20.4	(25) 16.4	(20) 16.2
Sugar, dry basis	(0) 16.40	(5) 30.92	(10) 38.13	(15) 45.10	(20) 57.88	(25) 59.42	(0) 12.51	(5) 38.84	(10) 46.36	(15) 51.94	(20) 58.15	(25) 59.00
Fresh basis	(0) 3.14	(5) 6.19	(10) 6.91	(20) 7.86	(15) 8.27	(25) 8.78	(0) 3.24	(5) 8.50	(20) 9.43	(25) 9.72	(10) 9.94	(15) 10.37
Fresh basis adjusted	(0) 3.14	(5) 5.47	(10) 5.79	(20) 6.01	(25) 6.42	(15) 6.60	(0) 3.24	(5) 7.85	(20) 8.18	(25) 8.22	(10) 9.02	(15) 9.16

Starch

	Baby Blue						*Blue Hubbard*					
Starch, dry basis	(0) 49.97	(5) 31.58	(10) 18.05	(15) 18.04	(25) 14.13	(20) 11.54	(0) 50.80	(5) 25.82	(10) 8.29	(20) 2.22	(25) 2.05	(15) 0.71
Fresh basis	(0) 11.98	(5) 8.50	(10) 4.32	(15) 3.92	(25) 2.99	(20) 2.94	(0) 11.24	(5) 4.54	(10) 1.21	(25) 0.25	(20) 0.22	(15) 0.11
Fresh basis adjusted	(0) 11.98	(5) 7.50	(10) 3.66	(15) 3.20	(25) 2.37	(20) 2.36	(0) 11.24	(5) 4.19	(10) 1.11	(25) 0.22	(20) 0.19	(15) 0.10

	Buttercup						*Silver Bell*					
Starch, dry basis	(0) 61.08	(5) 37.92	(10) 36.74	(15) 13.44	(20) 9.86	(25) 9.42	(0) 58.62	(5) 40.93	(10) 25.27	(15) 15.44	(20) 13.48	(25) 8.18
Fresh basis	(0) 18.54	(10) 11.09	(5) 10.91	(15) 3.15	(20) 2.39	(25) 2.08	(0) 14.69	(5) 9.41	(10) 5.72	(15) 3.32	(20) 2.82	(25) 1.60
Fresh basis adjusted	(0) 18.54	(5) 9.79	(10) 9.57	(15) 2.70	(20) 1.96	(25) 1.68	(0) 14.69	(5) 8.79	(10) 5.16	(15) 2.94	(20) 2.44	(25) 1.37

	Butternut						*Sweet Meat*					
Starch, dry basis	(0) 54.45	(5) 40.06	(10) 27.56	(15) 19.45	(20) 9.07	(25) 3.05	(0) 56.26	(5) 31.67	(10) 24.30	(15) 10.29	(20) 3.25	(25) 2.73
Fresh basis	(0) 10.37	(5) 8.00	(10) 5.03	(15) 3.56	(20) 1.24	(25) 0.44	(0) 14.60	(5) 7.40	(10) 5.60	(15) 2.33	(20) 0.59	(25) 0.52
Fresh basis adjusted	(0) 10.37	(5) 7.08	(10) 4.23	(15) 2.83	(20) 0.94	(25) 0.32	(0) 14.60	(5) 6.83	(10) 5.08	(15) 2.07	(20) 0.51	(25) 0.43

[a] Mean of four replications, expressed as per cent.
[b] Any two means *not underscored* by the same line are *significantly different*. Any two means *underscored* by the same line are *not significantly different*.
[c] Same percentages hold also for starch.
[d] Number of weeks of storage.

and constituent analyses. As far as the authors can determine, constituent content of three of the six varieties investigated has not been reported previously in the literature.

Experimental

The varieties studied during 1957–58 were Baby Blue, Buttercup, Blue Hubbard, Silver Bell, and Sweet Meat of the *Cucurbita maxima* species and Butternut of the *C. moschata* species. The six varieties were grown on the University Horticultural farm using randomized complete block design with four replications. The squashes were harvested between September 17 and 20 and placed in storage on slatted racks, keeping the fruit from the 24 plots separated.

During the first week of storage the temperature averaged 23° C. The average temperature for the remaining 20 weeks of storage was 9° C.

The relative humidity in the storage room averaged 63% during the first week with an average daily low of 57% and an average daily high of 68%. The corresponding humidity figures for the remaining 24 weeks of storage were 46, 42, and 50%, respectively.

To determine the mean weight loss of each variety, 10 squashes from each plot were weighed individually each week. The additional individual squashes remaining in storage (from 15 to 40 per plot) were weighed monthly. The result indicated that the mean weight loss of 10 fruit was representative of each respective plot.

At harvest and thereafter at five 5-week intervals, a representative fruit of each variety from each replication was taken from storage, its weight loss determined, and a sample of the raw edible portion analyzed for total solids, total sugar, and starch. In some instances, in the case of the Baby Blue and Butternut varieties, two squashes were used in order to secure enough material for analysis. To avoid any effect due to differences in composition of different parts of the squashes, each was cut into eight parts and a total of 700 grams secured by taking a longitudinal section from each piece. This was cubed and blended with 700 ml. of distilled water. The water was increased to 1050 ml. for the Baby Blue variety after the first sampling date because the blend was too thick. This was also done with the Blue Hubbard samples from two replications on the last sampling date. The total of 700 grams was required in order to provide sufficient material for the determination of other nutrients which were being studied concurrently.

For total solids, aliquots of the squash-water slurries were dried at 70° C. in a forced draft oven and then the drying was completed at 70° C. in a vacuum oven.

Total sugar was determined by an adapted method of the Association of Official Agricultural Chemists (*1*).

Starch was determined by a modification of the method of McCready *et al.* (*14*).

Preference was evaluated on the basis of flavor and texture by members of the Home Economics staff 1 week after harvest and thereafter at four 5-week intervals. Although the women received some instruction in judging, they could not be considered trained judges. Taste tests were conducted in the morning and afternoon of one day and in the morning of the following day. The judges were not aware of the identity of the varieties.

To prepare the samples, 700 grams of unpeeled squash of each variety were placed in a casserole, 50 ml. of water added, covered and baked 60 minutes at 190° C. A warm, 50-gram sample of each variety was presented to each judge under a code number which was changed at each tasting session. Each sample was rated first on a separate schedule for flavor and then on a schedule for texture using a scale from 1 (dislike extremely) to 8 (like extremely). Judges were isolated from each other in booths with a constant light intensity.

Five judges participated in all five of the triplicate taste-testing sessions. An additional six judges scored the samples at each taste-testing session. These six judges were not always the same individuals in each sampling period. The judges exhibited individual differences in the range of judgments recorded and therefore the scores given the six varieties by each judge at each tasting session were ranked. Associations between nutrient content and preference were determined by calculating the correlation coefficients between these ranks and the constituent content of the squashes.

Results and Discussion

The results of the chemical analyses are presented in Tables I to III. Total sugar and starch content are shown in Tables I and II. The figures are the means of four replications and have been arranged in Table I by sampling dates and in Table II by varieties. The findings are expressed on both the dry and fresh basis as the latter are influenced by certain significant differences and decreases in total solids content found between varieties and during storage. Total solids values are included in the tables.

Blue Hubbard and Butternut were lower than Buttercup in total solids content at harvest and retained these relative positions throughout storage. Phillips (*15*) in a study of changes during 3 months of storage of the same three varieties found a similar relationship at harvest and after storage as did Holmes, Smith, and Lachman (*6*) after 6 weeks of storage. The total solids content of Buttercup and Butternut in this study approximates those reported in the literature (*6, 7, 9, 10, 11, 15, 16*). The total solids content at harvest and subsequent rapid loss in Blue Hubbard found in this study are in contrast to the findings of other workers who in general report a lower percentage content at harvest and very little loss during storage (*2, 3, 6, 8, 15, 17*). This apparent discrepancy may be due to the rapidity of the change in total solids of this variety which necessitates a minimum of delay between harvest and analysis if the maximum change is to be observed.

The fresh basis figures for content of sugar and starch were also adjusted for weight loss of squashes during storage in order to evaluate the absolute changes. The mean weight loss of the six varieties ranged from 14 to 28%. Approximately one half of the ultimate weight loss during the 25-week storage period occurred in the first 5 weeks. The adjusted-fresh basis figures are the sugar and starch content expressed in percentage of 100 grams of fresh weight at harvest. The reason for making this adjustment has been discussed in a previous paper (*12*).

An analysis of variance showed no significant differences among replications for sugar and starch expressed on the dry, fresh, or adjusted-fresh basis. The highly significant differences among varieties and sampling dates were investigated further by Duncan's multiple range test (*5*) to determine specific differences between varieties and between sampling dates. Since this paper is concerned for the most part with relationships between preference and constituent content, emphasis is placed on values expressed on the fresh basis. In the following discussion, significance refers to the 1% level of probability, unless otherwise stated.

Sugar. At harvest, there was no difference between the sugar content of the six varieties on the dry, fresh, or adjusted-fresh basis (Table I). Total sugar increased in all varieties during storage. During the first 5 weeks the increase was greatest in Buttercup. After 10 weeks of storage the sugar content of Buttercup, Silver Bell, and Sweet Meat had increased nearly threefold and was significantly higher (fresh basis and adjusted-fresh basis) than the sugar content of Baby Blue, Butternut, and Blue Hubbard. These two groups of squashes maintained this relative sugar content throughout the remaining 15 weeks of storage. At the end of the storage period, Buttercup and Silver Bell were significantly higher than Baby Blue and Blue Hubbard.

Each variety had a significantly higher content of sugar (fresh and adjusted-fresh basis) after 5 weeks of storage (Table II). There were no further significant changes after 5 weeks of storage for Baby Blue, Buttercup, Blue Hubbard, Sweet Meat, and, for all practical purposes, Butternut. The Silver Bell variety did not reach its maximum content until after 10 weeks of storage and then maintained this level throughout the remainder of the storage period. Adjustment for weight did not materially affect the findings. All varieties showed additional significant increases in sugar content expressed on the dry basis reflecting the significant decreases in total solids.

Phillips (*15*) found little difference between the sugar content (fresh basis) of Blue Hubbard, Buttercup, and Butternut at harvest. After 3 months of storage, Blue Hubbard had the least percentage increase in sugar content of the three varieties. Other values reported in the literature for sugar content of Blue Hubbard, Buttercup, and Butternut determined with no delay between harvest and analysis are reasonably similar to those found in this study. When a delay occurred between harvest and analysis the values are higher and probably reflect the rapid increase in sugar content following harvest. More frequent analyses during the early part of storage are needed to evaluate properly the rate of this increase.

Starch. At harvest the starch content (fresh and adjusted-fresh basis) of Baby Blue, Blue Hubbard, and Butternut was significantly lower than that of Buttercup (Table I). This was due to differences in total solids, since on the dry basis, the six varieties did not differ from each other.

As expected, starch content decreased throughout the period of storage. Since the rate of decrease in both total solids and starch differed among the varieties, significant differences in starch content between the six varieties were not the same in each sampling period. Baby Blue and Blue Hubbard ranked low (4th and 5th) in starch and total solids content at harvest. After 15 weeks of storage and thereafter, Baby Blue ranked highest and Blue Hubbard lowest in starch content. During storage, Baby Blue had the least decrease and Blue Hubbard the greatest decrease in total solids and starch content. After 25 weeks of storage, Baby Blue still had approximately one fourth of the starch content at harvest and 86% of the total solids, while Blue Hubbard had practically no starch and only 50% of the total solids. The values of starch content on the various sampling dates in Table II show the continuous decrease in starch during the storage period. The mean starch content of the six varieties decreased 90% during 25 weeks of storage. The major decrease of 60% occurred during the first 10 weeks.

The percentages of starch (fresh basis) at harvest contained in Blue Hubbard, Buttercup, and Butternut were similar to the values found by Phillips (*15*). In both studies Buttercup ranked higher in starch than the other two varieties. Our findings are in agreement with the reported almost complete disappearance of starch during storage (*2*, *9*, *11*, *15*, *17*).

Table III. Correlation Coefficients (*r*) between Flavor and Texture, and Sugar (Fresh Basis), Starch (Fresh Basis), and Total Solids Content of Six Varieties of Winter Squashes

Variety	Sugar, %		Starch, %		Total Solids, %	
	Flavor	Texture	Flavor	Texture	Flavor	Texture
Buttercup	0.796[a]	0.612[b]	−0.537[b]	−0.726[a]	−0.294	−0.614[b]
Silver Bell	0.682[a]	0.526[b]	−0.674[a]	−0.518[b]	−0.608[b]	−0.399
Baby Blue	0.008	0.614[b]	0.212	−0.525[b]	0.330	−0.093
Blue Hubbard	−0.560[b]	−0.638[b]	0.600[b]	0.692[a]	0.589[b]	0.677[a]
Butternut	0.307	−0.580[b]	−0.091	0.742[a]	0.306	0.697[a]
Sweet Meat	−0.407	0.050	0.337	0.034	0.129	−0.024

[a] Significant at 1% level. [b] Significant at 5% level.

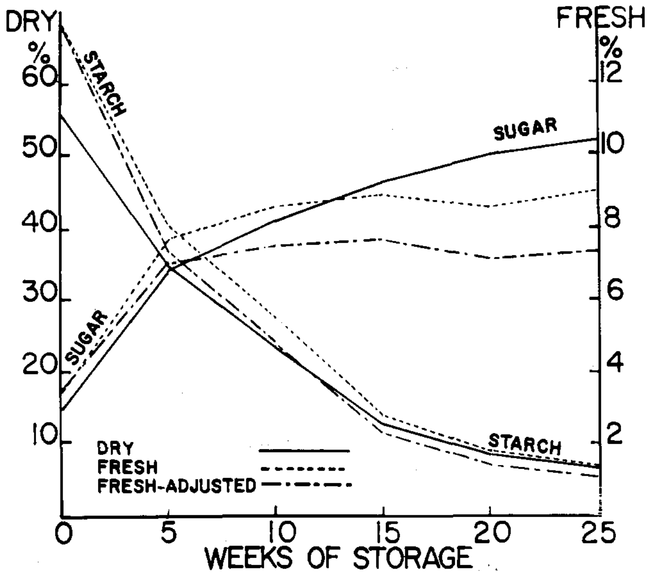

Figure 1. Mean total sugar and starch content of six varieties of winter squash during storage

Sugar-Starch Relationship. The inverse relationship between sugar and starch content during storage was found to be highly significant for each variety on the dry, fresh, and adjusted-fresh basis. Buttercup, Silver Bell, and Sweet Meat, the three varieties that ranked highest in starch at harvest, ranked highest in sugar at the end of the storage period. However, the increase in sugar and decrease in starch occurred at different rates.

While the major sugar accumulation occurred within the first 5 weeks of storage with little or no change thereafter, starch decreased in an exponential fashion throughout storage. Subsequent work with the Butternut variety indicated the increase in sugar is most pronounced during the first 2 weeks after harvest.

The mean percentage of sugar and starch of the six varieties at each sampling date on the dry, fresh, and adjusted-fresh basis is presented in Figure 1. The ratio of sugar to starch was approximately the same for all six varieties at harvest with an average of 0.25. After 5 weeks, the ratios had increased to approximately 1.00 as a result of both an accumulation of sugar and a decrease in starch. The subsequent increases in the ratios toward the end of storage were due primarily to the continuous decrease in starch. This decrease was greatest for Butternut, Blue Hubbard, and Sweet Meat resulting in higher sugar-starch ratios as compared with the other three varieties.

Preference. The results of the taste testing were examined for possible relationships between the degree of preference on the basis of flavor and texture and changes in sugar, starch, and total solids.

Using data from either the five regular judges or all judges, Buttercup, Silver Bell, and Sweet Meat, the three varieties highest in total sugar, had higher average flavor ranks in each of the five sampling periods and thus were preferred to Baby Blue, Blue Hubbard, and Butternut—the varieties with the lower sugar content. This average flavor rank increased progressively for the first group of squashes and decreased progressively for the second group.

A distinction between the two groups of squashes on the basis of texture did not become apparent until the third sampling period which coincides approximately with the time the sugar content had begun to exceed the starch content. At this time, and at the two remaining sampling periods, the average rank based on texture was higher for the Buttercup, Silver Bell, and Sweet Meat varieties than for the other three.

Since the squashes used in the taste tests were not the same fruits sampled for chemical analysis, the correlation coefficients between preference and constituent content were calculated using the mean of the chemical analyses of the four replicates with each of the three mean flavor and texture ranks obtained at each taste testing session from the five regular judges. These correlation coefficients ($n = 15$) are presented in Table III.

Examination of this table indicates two distinct groups of squashes which can also be differentiated on the basis of the sugar-starch ratios in the latter part of the storage period. Buttercup, Silver Bell, and Baby Blue, the varieties with a relatively low sugar-starch ratio, had a positive association between sugar content and ranks for flavor and/or texture, and a negative association between starch content and ranks for flavor and/or texture. In contrast, Blue Hubbard and Butternut, the varieties with a relatively high sugar-starch ratio, had, with one exception, a negative association between sugar content and ranks for flavor and texture and a positive association between starch content and ranks for flavor and texture. The associations between total solids content and ranks for flavor and/or texture were in general similar to those between starch content and ranks for flavor and/or texture. The probability levels of significance are indicated in Table III.

Blue Hubbard and Butternut were relatively low in sugar. The tendency of a negative association between sugar content and degree of preference for these two varieties suggests that the "low sugar" varieties are less acceptable when the starch and total solids are at a minimum—that is, in the latter part of storage. Although Baby Blue also tended to be low in sugar, its total solids content as well as the sugar-starch ratio approximated that of the higher sugar content group. Preference appears to be influenced not only by the absolute sugar and starch content but also by the sugar-starch ratio and by total solids content.

Undoubtedly compounds other than sugar and starch, possibly protein and lipide degradation products, influence the quality of winter squashes. Investigations to identify such compounds would be warranted.

Acknowledgment

The authors wish to thank Elizabeth M. Elbert for her assistance in conducting the laboratory analyses and taste testing.

Literature Cited

(1) Assoc. Offic. Agr. Chemists, Washington D. C., "Official Methods of Analysis," 8th ed., p. 550, 1955.
(2) Culpepper, C. W., Moon, H. H., *J. Agr. Research* **71,** 111 (1945).
(3) Cummings, M. B., Jenkins, E. W., *Vermont Univ. Agr. Expt. Sta. Bull.* **251** (1925).
(4) Cummings, M. B., Stone, W. C., *Ibid.*, **222** (1921).
(5) Duncan, D. B., *Biometrics* **11,** 1 (1955).
(6) Holmes, A. D., Smith, C. T., Lachman, W. H., *Food Research* **13,** 123 (1948).
(7) Holmes, A. D., Spelman, A. F., *Ibid.*, **11,** 345 (1946).
(8) Holmes, A. D., Spelman, A. F., Rogers, C. J., Lachman, W. H., *Ibid.*, **13,** 304 (1948).
(9) Holmes, A. D., Spelman, A. F., Wetherbee, R. T., *Ibid.*, **19,** 293 (1954).
(10) Holmes, A. D., Spelman, A. F., Wetherbee, R. T., *Food Technol.* **3,** 269 (1949).
(11) Holmes, A. D., Spelman, A. F., Wetherbee, R. T., *J. Am. Dietet. Assoc.* **30,** 138, (1954).
(12) Hopp, R. J., Merrow, S. B., Elbert, E. M., *Proc. Am. Soc. Hort. Sci.* **76,** 568 (1960).
(13) LeClerc du Sablon, M., *Compt. rend.* **140,** 320 (1905).
(14) McCready, B. M., Guggolz, J., Silviera, V., Ownes, H. S., *Anal. Chem.* **22,** 1156 (1950).
(15) Phillips, T. G., *Plant Physiol.* **21,** 533 (1946).
(16) Yeager, A. F., Latzke, E., *N. Dakota Agr. Expt. Sta. Bull.* **258** (1932).
(17) Yeager, A. F., Richards, M. C., Phillips, T. G., Levcowich, T., Barratt, R. W., *New Hampshire Agr. Expt. Sta. Bull.* **356** (1945).

Received July 28, 1960. Accepted November 3, 1960. Vermont Agricultural Experiment Station Journal Series Paper No. 96.

QUALITY OF DAIRY PRODUCTS

Vitamin A, Carotenoid, Iodine, and Thiocyanogen Values, and the Refractive Index of Milk Fat as Influenced by Feed, and by Individual and Breed Differences

VLADIMIR N. KRUKOVSKY

Department of Dairy and Food Science, New York State College of Agriculture, Cornell University, Ithaca, N. Y.

THE VALUE of milk and its products in diet makes it very desirable that they should be produced in such a way as to make them palatable, nutritious, and fairly resistant to oxidation which accounts for objectionable flavors. Although fat in fresh milk is relatively stable, it is unstable in frozen cream and butter and may undergo deterioration if used in reconstituted milk (*9*, *12*).

The carotenoid–vitamin A–tocopherol relationship (*3*, *7*, *10*, *11*) and the part played by tocopherols and feed in the stabilization of fresh milk appear to be well established; other relationships such as between color intensity of milk fat, palatability of fresh milk, and inhibition of flavor defects (*4*, *6*) or between vitamin A activity and the keeping quality of butter (*13*) are not yet well known. This investigation presents a comparison of refractive index, vitamin A, carotenoid, iodine, and thiocyanogen values of milk fat from 28 cows of different breeds as influenced by the type of roughage fed consecutively to the same cows, breed differences, and physiological response of individual cows to feed consumed.

Studies on the effect of breed and feed on the palatability of fresh cream and butter and on the storage stability of fat in frozen cream and butter are now in progress.

Experimental

Jersey, Brown Swiss, Holstein-Friesian, and Ayrshire cows were placed in groups