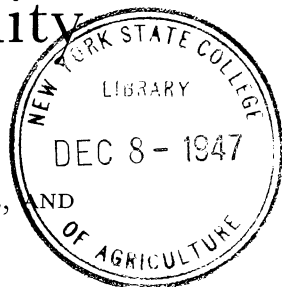


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Chemical Composition and Freezing Adaptability of Strawberries

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*Strawberry Seedling and Variety Collection
from Which Samples were Taken for These Studies*

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ABSTRACT

RESULTS are presented of studies on the ascorbic acid content, color, soluble solids, free acids, and pH of over 300 named varieties and seedling selections of strawberries. Thirty-five named varieties are rated for their suitability for preservation by freezing.

The chemical characteristics of the strawberries were compared when grown at two different locations and in two successive years.

Distribution graphs are used to show the variability of the chemical properties studied. Although correlations were attempted between the various properties, the only correlations found to be significant were between free acids and pH and between color and pH.

Freezing adaptability could not be related to any of the chemical properties studied.

Strawberries were found to be an excellent source of ascorbic acid. Over 80 per cent of the varieties tested fell between 50 and 80 mgm per cent on the fresh fruit basis.

Of the 35 named varieties compared, Julymorn, Marshall, Redheart, Redwing, Sparkle, and Vanrouge were rated as good for freezing.

CHEMICAL COMPOSITION AND FREEZING ADAPTABILITY OF STRAWBERRIES

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INTRODUCTION

STRAWBERRIES are one of the important small fruit crops grown in New York State. From 1934 to 1943, an average annual production of 327 thousand crates with an average value of over a million dollars was maintained. In 1945, although production dropped considerably, the dollar value rose to over two and a half million (17).¹

Strawberries are put to a wide variety of uses, and it is not always recognized that the best variety for one commercial purpose may not necessarily be the best for another. For example, in the ice cream trade, a deep red color and strong flavor are desirable; the canning and preserving trades like berries that are deep red to the center, firm, and sub-acid to acid in flavor; while in the fresh fruit market, a sub-acid to mild sub-acid flavor is often preferred, and texture is not so important.

The object of the present study was to determine varietal differences in freezing adaptability and in ascorbic acid content, color, soluble solids, free acids, and pH. It was believed that the survey of over 300 varieties and seedling selections reported here would give useful information on the relation of quality to the chemical composition of strawberries.

REVIEW OF THE LITERATURE

Little has been reported on the relation of variety to the chemical composition of the strawberry, although several investigators have reported a considerable range in the ascorbic acid content of different varieties (1, 3, 4, 6, 9, 11, 13). In a preliminary report (14), the 1945 ascorbic acid results reported here were presented with attention being given to possible influence of parentage.

Since the strawberry has been shown to contain citric acid and a smaller amount of malic acid (10), the free acid results are expressed as percentage of citric acid. Chatfield and McLaughlin (2) give an average of 1.09 per cent as the total acid content calculated as citric

¹ Refers to Literature Cited, page 13.

acid, and also report water, protein, fat, ash, carbohydrates, and caloric values in their compilation.

Hinton and Macara (5) reported the insoluble solids, seeds, free acid, total acid, lead numbers, pectin, and pH of 28 miscellaneous samples of strawberries. However, the value of the work to investigators in this country is probably small because of the differences in climate and varieties, as well as the small number of samples studied. Kudryavtseva (7) found that total sugars were lower in wet seasons than in dry seasons and that the water content of the strawberry also varied with the rainfall.

EXPERIMENTAL PROCEDURE

CULTURAL CONDITIONS

In 1945, 36 named strawberry varieties and about 275 unnamed seedling selections were grown in a Station variety test plot located on a light sandy loam soil 5 miles north of Geneva, N. Y. In 1946, 33 varieties and 75 of the selections were tested again at the same location, hereinafter referred to as location 1. A similar collection of varieties and seedlings were grown on a clay-loam soil at Geneva (location 2). The strawberries were picked when they were judged to be medium or "table" ripe.

SAMPLING AND METHODS

From about a quart of fruit from each variety and seedling, 20 berries were selected at random for the ascorbic acid analyses. Transverse center sections of the 20 berries were cut directly into 5 per cent metaphosphoric acid and the composite sample homogenized in a Waring Blendor and filtered through No. 2 Whatman filter paper. The juice was pressed from the remainder of the berries and was used for color, free acid, Brix degrees, and pH determinations.

Ascorbic acid determinations were made by the indophenol-xylene extraction method (12) on the metaphosphoric acid extracts. All analyses were completed on the day of sampling.

Color estimations were made with the Beckman quartz spectrophotometer in 1 cm Corex cells. It was found that every variety and selection had its maximum absorption peak at 500 m μ and therefore only the optical density at 500 m μ is reported. There is little interference from pigments other than the anthocyanins at this wave length in fresh strawberries. After diluting the juice to a convenient degree with distilled water, the optical density was read on the spectrophotometer. The resulting density multiplied by the dilution factor is directly related to intensity of the red color of the strawberry juice.

Brix readings were made with a Bausch and Lomb hand refractometer. The degrees Brix may be interpreted as an approximation of the percentage of soluble solids.

pH of the juice was determined with a Beckman, Model G, pH meter.

Free acids were measured by diluting 5 ml of juice with about 200 ml of distilled water. The diluted juice was then titrated with 0.1 N sodium hydroxide, using phenolphthalein as the indicator. The acidity is expressed on the basis of grams of anhydrous citric acid per 100 ml of juice.

Freezing preservation tests were made by slicing the berries into $\frac{1}{4}$ to $\frac{1}{2}$ -inch segments and packing with 1 part of sugar to 4 parts of fruit in 1-pint, tub-shaped containers.² The sliced berries were frozen before an electric fan at -10° F and stored at -6° F for 6 months. After the storage period, the samples were given code numbers and submitted to a taste panel consisting of six experienced judges. The strawberries were given scores for flavor, texture, and color.

RESULTS

The data for the named varieties are presented in Table 1. It was considered that the data on seedling selections would not be of sufficient value to other investigators to warrant reporting individual results. However, since the distribution of seedling data for the various determinations closely approximated that of the named varieties, the results were all treated together in the statistical evaluation and graphical presentation of the data. Standard errors were determined according to the paired comparison method of Student (15), and correlation coefficients according to the method of Love (8).

ASCORBIC ACID

The distribution of the ascorbic acid values of 308 named varieties and selections in 1945 shows values ranging from 32 to 99 mgm per cent of ascorbic acid with an average of 66 (Fig. 1). Of the varieties tested, 112 were analyzed at least twice during the season. The standard deviation of a single sampling taken at different times during the season was ± 11.1 . Thirty per cent of the varieties fell in the 60 to 70 mgm per cent classification, and 82 per cent fell between 50 and 80 mgm per cent.

The comparison of two years' data on 23 named varieties and 59 selections showed an average ascorbic acid value of 66.4 mgm per cent for 1945 and 79.9 mgm per cent for 1946. The 20 per cent increase in ascorbic acid content of the 1946 berries over those of 1945 proved to be statistically significant ($t = 8.86$ for 81 comparisons). A similar comparison made on strawberry varieties planted on the two different farms in the same year showed that those grown on location 1 had an average ascorbic acid value of 76.2 mgm per cent, while those grown

² Kindly supplied by the Lily-Tulip Cup Corp., New York, N. Y.

TABLE 1.—CHEMICAL COMPOSITION AND COLOR OF STRAWBERRY VARIETIES.

VARIETY	ASCORBIC ACID, MG/M PER CENT		COLOR DENSITY*		pH		FREE ACID, PER CENT		BRUX READING	
	1945	1946	1945	1946	1945	1946	1945	1946	1945	1946
Aberdeen.....	41.4	43.1	2.63	—	3.37	—	1.23	—	7.4°	—
Beacon.....	—	96.7	—	2.28	—	3.66	—	0.95	—	8.1°
Bliss.....	54.8	—	2.36	—	3.60	3.52	0.68	0.73	6.1°	8.0°
Boquet.....	53.4	—	1.78	—	3.57	—	0.75	—	5.3°	—
Brightmore.....	55.6	—	3.23	2.14	3.55	3.68	0.79	0.64	5.6°	5.0°
Bristol.....	—	86.2	—	1.48	—	3.64	—	0.91	—	7.9°
Camden.....	69.1	74.5	4.41	3.67	3.65	3.62	0.76	0.78	6.7°	7.2°
Cato.....	45.2	64.9	2.01	3.26	3.68	3.61	0.62	0.80	5.0°	6.3°
Catskill.....	81.1	—	3.60	—	3.63	—	0.90	—	7.5°	—
Clermont.....	50.7	77.4	1.96	2.40	3.65	3.50	0.68	0.73	5.0°	7.0°
Crimson Glow.....	62.1	71.7	3.60	2.77	3.64	3.66	0.78	0.87	7.3°	6.4°
Culver.....	49.6	—	5.27	—	3.68	—	0.86	—	5.3°	—
Daybreak.....	73.0	62.3	2.50	3.08	3.83	3.71	0.96	0.67	9.1°	6.8°
Dorsett.....	49.6	75.5	4.39	2.89	3.58	3.67	0.90	0.77	7.6°	8.0°
Dresden.....	72.6	95.0	2.83	2.59	3.67	3.66	0.90	0.80	7.0°	8.5°
Early Cheyenne No. 1.....	—	67.0	—	3.85	—	3.55	—	0.79	—	7.0°
Eleanor Roosevelt	59.4	—	2.73	—	3.81	—	0.75	—	6.2°	—
Fairfax.....	62.1	96.7	3.54	2.09	3.78	3.84	0.80	0.55	8.5°	8.1°
Gem.....	65.9	—	4.43	—	3.37	—	1.23	—	5.3°	—
Howard 17 (Pre- mier).....	54.9	69.4	3.65	—	3.56	—	0.86	—	6.3°	—
Julymorn.....	57.8	80.6	6.42	—	3.57	—	0.83	—	5.6°	—
Marshall.....	49.4	—	2.63	—	3.69	—	0.75	—	6.4°	—
Massey.....	58.4	66.1	2.15	—	3.79	—	1.01	—	8.2°	—
Mastodon.....	71.9	79.4	5.71	2.92	3.48	3.48	1.01	0.72	6.6°	5.1°
Maytime.....	57.8	71.2	1.78	2.00	3.77	3.88	0.79	0.57	5.6°	6.7°
Midland.....	64.8	83.4	4.21	3.36	3.73	3.58	0.85	0.55	6.8°	7.4°
Pathfinder.....	55.1	56.2	2.56	2.11	3.52	3.72	0.96	0.74	6.3°	6.0°
Paymaster.....	58.3	63.1	2.31	1.83	3.63	3.83	0.82	0.64	5.5°	7.0°
Redheart.....	69.7	75.0	6.48	5.08	3.58	3.78	0.98	0.94	7.2°	9.7°
Redstar.....	—	74.2	—	3.25	—	3.62	—	0.73	—	6.6°
Redwing.....	73.6	71.3	3.40	2.19	3.73	3.59	0.94	0.67	9.0°	6.5°
Robinson.....	70.3	71.7	2.33	2.44	3.67	3.76	0.70	0.61	6.7°	6.9°
Shelton.....	—	85.8	—	1.27	—	3.67	—	0.82	—	7.4°
Sparkle.....	65.9	83.4	3.05	2.52	3.67	3.75	0.87	0.54	7.1°	6.6°
Starbright.....	55.6	—	2.02	—	3.91	—	0.62	—	7.4°	—
Suwannee.....	—	72.5	—	3.10	—	3.52	—	1.04	—	10.0°
Temple.....	63.0	63.1	—	2.29	3.85	3.78	0.79	0.58	9.2°	6.6°
Tenn. Beauty.....	75.7	79.0	2.74	2.02	3.64	3.74	0.88	0.85	7.2°	6.8°
Tenn. Shipper.....	75.7	—	4.53	—	3.53	—	1.01	—	5.0°	—
Tenn. Supreme.....	54.6	67.8	5.79	3.01	3.62	3.82	0.91	0.77	5.6°	6.6°
Valentine.....	71.0	74.5	5.83	3.66	3.57	3.47	0.99	0.67	6.6°	5.3°
Vanrouge.....	77.8	81.9	7.92	9.30	3.57	3.64	0.96	0.97	6.8°	7.6°
<i>F. virginiana</i> 27.....	—	60.9	—	2.64	—	3.55	—	1.49	—	8.6°

*Measured in Beckman quartz spectrophotometer at 500 m μ .

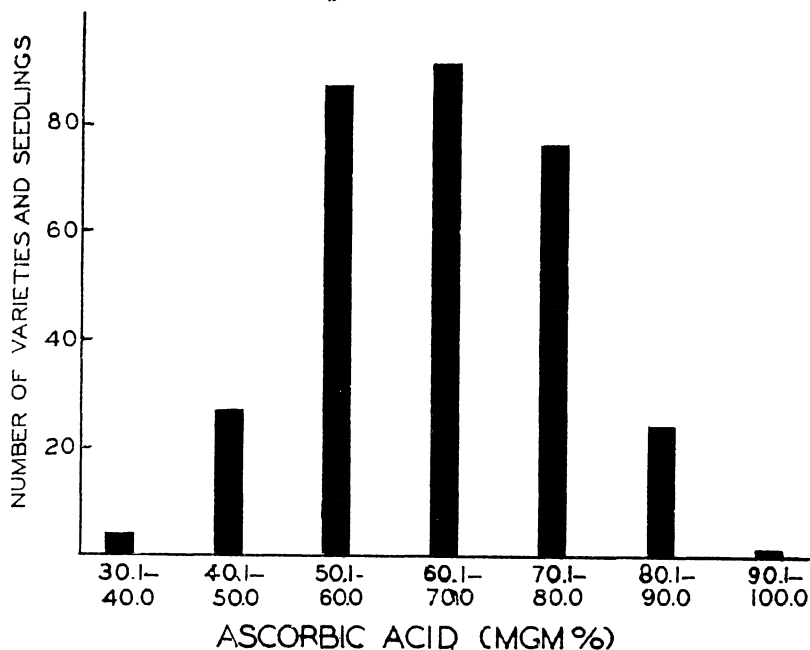


FIG. 1.—The Distribution of Ascorbic Acid Values of 308 Strawberry Varieties and Seedlings in 1945.

at location 2 had an average content of 64.7 mgm per cent. A “t” value of 6.43 for 45 comparisons showed this difference to be significant also.

Of the more common varieties tested (Table 1), Beacon, Bristol, Catskill, Dresden, and Fairfax are above average in ascorbic acid content. Aberdeen, Pathfinder, Marshall, and Dorsett were found to be below average.

COLOR

Strawberry anthocyanins increase their color intensity with decreasing pH, but the absorption peak remains at 500 m μ . The curve (Fig. 2) shows this relationship for one variety when the anthocyanin concentration is held constant and pH and optical density are allowed to vary. Ten 2-ml samples of juice were buffered over a pH range from 3.4 to 4.3, diluted to 10 ml, and the optical density measured at 500 m μ . The scatter diagram (Fig. 2) shows the range and distribution of the color density of the 1945 juices. Since all varieties do not fall on the line ($r = 0.52$), it is obvious that factors other than pH play an im-

portant role. The range of photometric densities varied from 0.98 to 9.30. Named varieties with notably high color values were Vanrouge, 7.92 and 9.30; Redheart, 6.48 and 5.08; Julymorn, 6.42; and Culver,

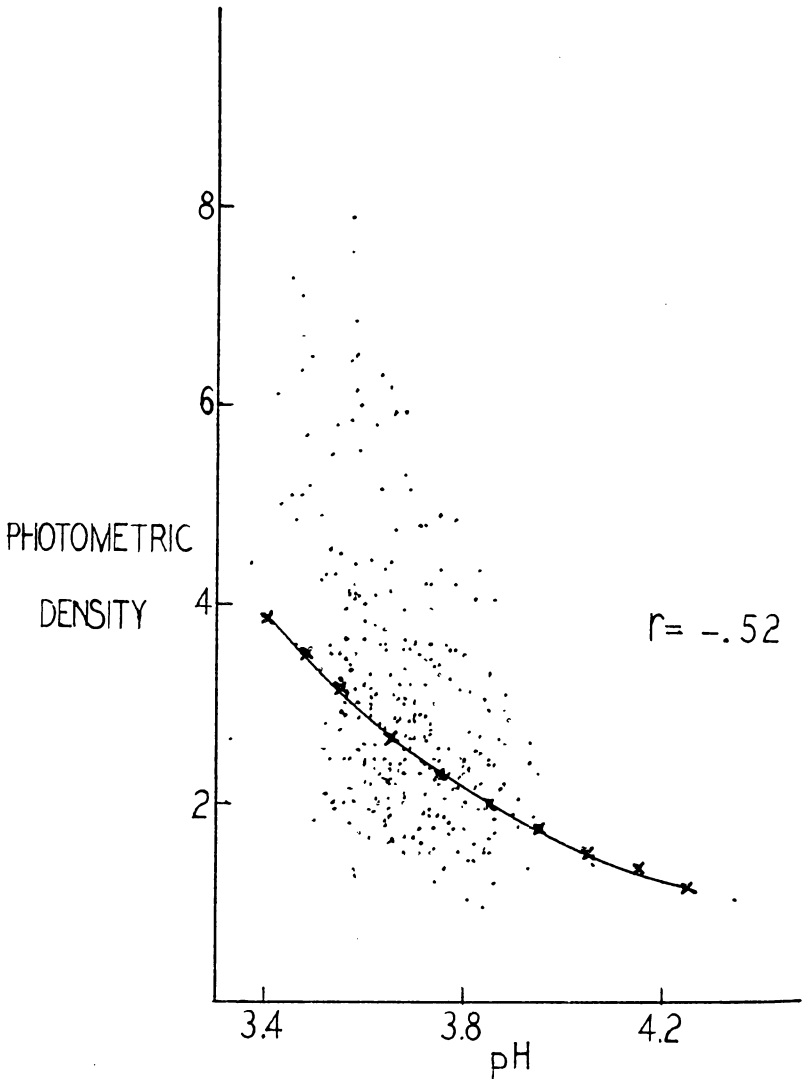


FIG. 2.—The Distribution and Relationship of the Color Density and pH of 308 Strawberry Varieties and Seedlings. The curve Shows the Effect of pH alone on the Optical Density of Strawberry Anthocyanin.

5.27. The standard deviation of the photometric density of a single sampling for a variety during the season was ± 1.31 .

The average density of 2.82 for the juice of the strawberries grown on location 1 in 1946 was significantly lower ($t = 3.68$ for 62 comparisons) than the 3.58 density of the same varieties in the same location in 1945 and also significantly lower than the 3.63 density of the varieties grown in location 2 the same year ($t = 3.72$ for 27 comparisons).

FREE ACIDS AND PH

The distribution of the 1945 results for pH and free acidity are shown in Fig. 3. The free acid values are expressed as grams of anhydrous citric acid per 100 grams of fresh weight. An "r" value of -0.57 shows the correlation between these two properties, although not so good as one might expect from such obviously related factors.

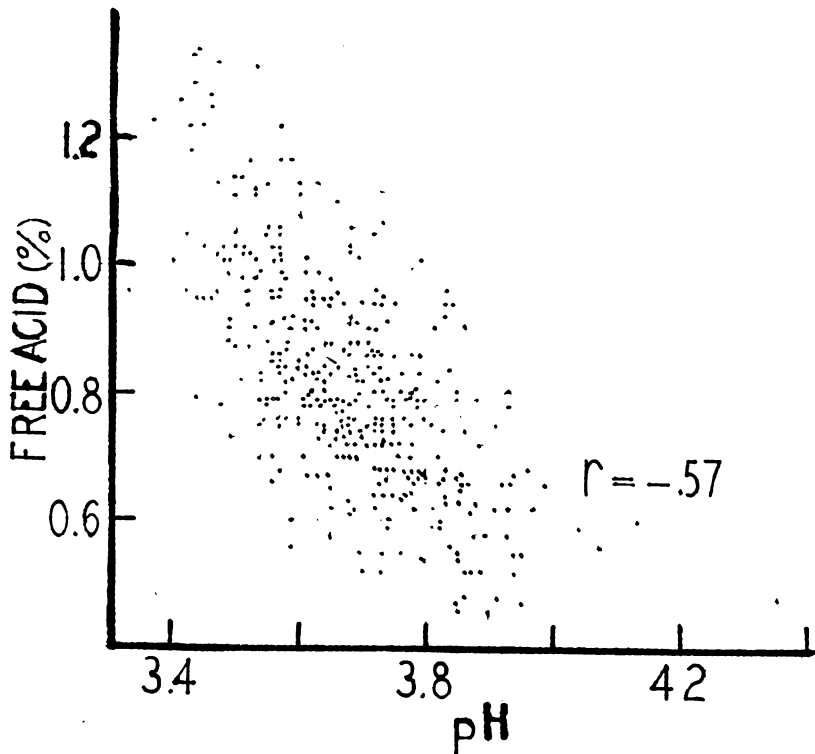


FIG. 3.—The Distribution and Relationship of pH and Free Acids of 308 Strawberry Varieties and Seedlings in 1945.

The standard error of a single sampling for pH was ± 0.14 and for total free acid was ± 0.13 . In 1945, the strawberries grown on location 1 had an average pH of 3.64, and a total acidity equivalent to 0.75 per cent of citric acid. In 1946, the average acidity was 0.79 per cent on the same location and 0.80 at location 2. These differences were not significant between years on the same location or between locations the same year. ($t = 1.47$ and 1.66 for comparison between years, of acidity and pH, respectively, for 63 comparisons. For the comparison between locations in 1946, the corresponding "t" values were 0.26 and 1.27 for 27 varieties.)

Gem, Aberdeen, and *Fragaria virginiana* (U. S. D. A. selection No. 27) were exceptionally high-acid varieties (Table 1). Of the 308 varieties tested, 80 per cent had pH values between 3.5 and 3.8 and free acid values between 0.60 and 1.00 per cent citric acid equivalent.

BRIX READINGS

An approximation of the percentage of soluble solids, degrees Brix, averaged 6.98° for 311 varieties and seedlings tested in 1945 at location 1 (Fig. 4). Eighty-seven per cent of the values fell between 5.1°

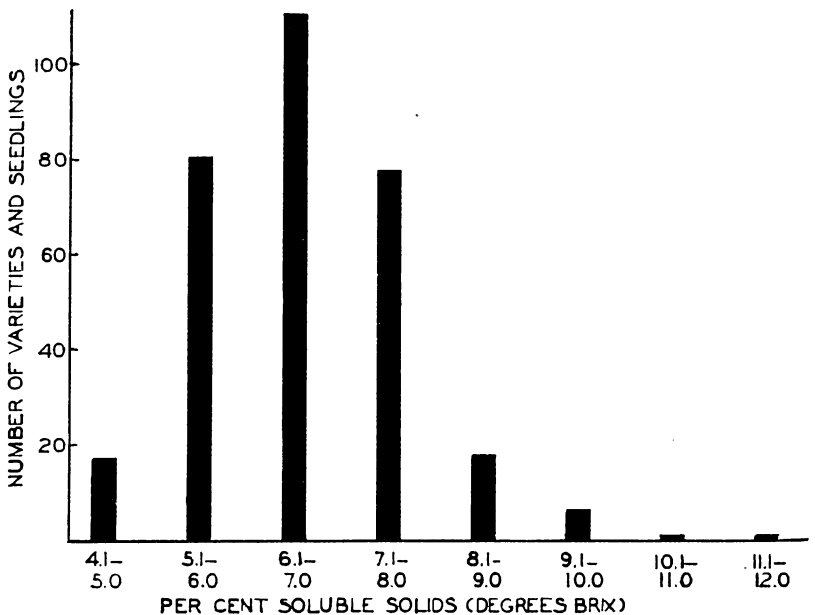


FIG. 4.—The Distribution of Total Soluble Solids Values of 311 Strawberry Varieties and Seedlings.

and 8.0°. The standard deviation of a single determination was ± 0.81 . The average for 1946 at the same location was 6.84°, which was not a significant difference ($t = 0.70$ for 63 comparisons). The comparison between location 1 and location 2 showed average Brix readings of 6.84° and 6.91°, respectively. This difference was also insignificant ($t = 0.67$ for 27 comparisons).

Fairfax, Redheart, Suwanee, and *Fragaria virginiana* 27 were exceptionally high in total soluble solids (Table 1).

The Brix readings were compared separately, as were pH and color in Fig. 2, with free acid, pH, color, and freezing adaptability, but no correlation whatsoever was obtained.

FREEZING SUITABILITY

Thirty-five varieties of strawberries were tested for suitability for preservation by freezing (Table 2). These tests extended over the

TABLE 2.—SUITABILITY OF VARIETIES GROWN IN NEW YORK STATE FOR PRESERVATION BY FREEZING, BASED ON QUALITY OF THAWED PRODUCT.*

GOOD QUALITY	YIELD	FAIR QUALITY	YIELD	POOR QUALITY	YIELD
Julymorn	Good	Brightmore	Good	Aberdeen	Good
Marshall	Medium	Camden	Good	Bliss	Poor
Redheart	Poor	Cato	Good	Boquet	Poor
Redwing	Medium	Catskill	Good	Clermont	Good
Sparkle	Good	Culver	Good	Crimson Glow	Medium
Vanrouge	Poor	Dorsett	Medium	Daybreak	Poor
		Dresden	Very g'd	Gem	Poor
		Eleanor Roosevelt	Poor	Pathfinder	Good
		Fairfax	Medium	Paymaster	Medium
		Howard 17 (Premier)	Good	Temple	Good
		Maytime	Medium	Tenn. Beauty	Medium
		Midland	Medium	Tenn. Supreme	Medium
		Robinson	Medium	<i>F. virginiana</i> 27	Medium
		Starbright	Poor		
		Tenn. Shipper	Medium		
		Valentine	Medium		

*The relative productivity that may be expected is also listed.

two-year period. None of them could be classed as excellent when considering the quality of the thawed product as served. Of the 35 varieties tested, only 6 were classed as good in quality. These included Julymorn, Marshall, Redheart, Redwing, Sparkle, and Vanrouge. Julymorn tends to have seedy tips, however, when grown in this area.

Sixteen of the total number were in the fair class. Among these are Catskill, which had previously been described as good when grown in

this area. It is possible that the length of time that this variety is in the optimum stage of ripeness for processing is rather short. Should this be the case, the chances of getting a good product from a given patch of berries would be lessened. Culver is another variety that was classified as yielding a frozen berry of good quality in previous studies but was now graded as fair. It was put into this classification because of the fact that the flavor of the thawed berries did not compare favorably with that of the others classed as good. Howard 17 (Premier) was also in the fair group, although in the past it was not classed as a particularly good berry for preservation by freezing. Frequently, the color and flavor of the product were not good when this variety was grown at Geneva. The results of the present study sustain the past judgment of the quality of this variety as a frozen strawberry.

DISCUSSION

The data presented in this paper show the degree of variability that may be expected in the various properties between varieties of strawberries as well as within varieties.

The difference in ascorbic acid between location as well as between years may be caused by a difference in sunlight intensity during ripening (4, 9).

The differences in color were opposite to those of ascorbic acid content. The 1946 strawberries from location 1 had the least color and the most ascorbic acid in both comparisons. This would indicate that conditions favorable to good color development are not the best for high ascorbic acid levels. Further work on the relationship of color, ascorbic acid, and sunlight intensity is planned for 1947.

It is interesting to note that no significant difference because of location or year was found in the comparison of total soluble solids, pH, or free acidity.

It was hoped that some correlation between freezing adaptability of a variety and one of the other properties studied might be discovered, but no such relation was found. Good quality of the frozen product seems to depend most often on the color and physical character of the fruit.

The relationship between pH and free acids is interesting. The general trend is shown in Fig. 3, but the great differences in buffering capacities among different varieties cause a rather wide scattering. These observations may be of practical importance in certain types of

processing where a change in pH will produce differences in flavor and other qualities. A highly buffered variety will have a more stable pH than one that is poorly buffered.

CONCLUSIONS

1. No relation was found between the freezing adaptability of a strawberry variety and any of the chemical constituents studied.

2. Extracts of all of the varieties and seedlings tested had maximum color absorption peaks at 500 m μ .

3. Sparkle and Julymorn are two of the best strawberry varieties for freezing purposes now grown in New York State.

4. There are great varietal differences in pH, free acid, ascorbic acid, total soluble solids, and color in strawberries, as well as differences that may be expected during the season in different samples of the same variety. Except for the correlation between pH and color and between pH and free acids, these properties do not correlate with each other.

5. Strawberries are a rich source of ascorbic acid, usually supplying between 50 and 90 mgm of vitamin C per 100 grams of fresh fruit. The amount of ascorbic acid varies widely among varieties as well as with growing conditions.

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