AN ABSTRACT OF THE THESIS OF

Ka-Teng Yao (Name) for the M. S. (Degree) in Food Tech. (Major)

Date thesis is presented May 10, 1951

Title Variation in the Sugar and Acid Content of Frozen Marshall Strawberries grown in Different Areas of the Pacific Northwest

Redacted for privacy

Abstract approved (Major Professor)

This study was undertaken to investigate the variation in the total sugar and acid content of the frozen Marshall strawberries grown in different areas of the Pacific Northwest.

The samples used in this study were collected from different freezing plants located in the states of Oregon and Washington during the 1949 strawberry season. Forty-four samples of Marshall strawberries were analyzed.

For total sugar determinations a modification of the Shaffer and Somogyi method was used. The average value found for total sugar was 7.56 per cent. The glass electrode was used for the determination of total acidity. The average value found for total acidity was 0.99 per cent. Soluble solids determined by the Bausch and Lomb hand refractometer had an average value of 9.90 per cent. The average pH value for all samples was 3.36.

The sugar and acid content of these Marshall strawberries showed most frequent distribution in the range from 7.1 to 9.0 per cent and 0.91 to 1.1 per cent, respectively. Soluble solids were most frequent in the range from 8.1 to 11.0 per cent.

No relationship was found for total sugar and acid content. Soluble solids were found to have a definite relationship with total sugar content.

Marshall strawberries grown in different areas of Oregon varied in total sugar and acid content. Generally, strawberries grown in warm areas and mature berries tend to have a higher sugar content. Berries grown on the hillsides and less mature berries tend to have a lower sugar content. The weather conditions apparently affect the sugar and acid content of Marshall strawberries greatly.

VARIATION IN THE SUGAR AND ACID CONTENT OF FROZEN MARSHALL STRAWBERRIES GROWN IN DIFFERENT AREAS OF THE PACIFIC NORTHWEST

by

KA-TENG YAO

A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1951

APPROVED:

Redacted for privacy

Professor of Food Technology

In Charge of Major

Redacted for privacy

Head of Department of Food Technology

Redacted for privacy

Chairman of School Graduate Committee

Redacted for privacy

Dean of Graduate School

Date thesis is presented May 10 1951

Typed by Lila Mae Clarno

ACKNOWLEDGMENT

The writer wishes to express his sincere appreciation to Dr. Thomas B. Niven, for his valuable guidance and suggestions in the preparation of this thesis.

Grateful acknowledgment is given to Dr. H. D. Reese of Chemistry Department for his suggestions in the experimental work.

To Mr. Jayantilal Shah and Mr. Edmund Wood, the writer wishes to express his appreciation for their indispensable assistance in some of the routine preparation and analyses.

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VARIATION IN THE SUGAR AND ACID CONTENT OF FROZEN MARSHALL STRAWBERRIES GROWN IN DIFFERENT AREAS OF THE PACIFIC NORTHWEST

I Introduction

Strawberry production is the most important small fruit crop in the Pacific Northwest and in the United States (23). In 1948 strawberry production in Oregon was 16.4 per cent, and Washington was 10.7 per cent, of the total tonnage produced in United States. In 1948 Oregon produced 1,650,000 crates while Washington produced 924,000 crates. The other leading strawberry producing states are California, Louisiana, Tennessee, and Virginia (15).

The strawberry has the ability to grow from sea level up to an elevation as high as 12,000 feet, in humid and dry areas, and in short- and long-day regions. Combined with its versatility of growth are its importance as the first berry to ripen during the season when few other local fruits are available and its dessert and processing qualities which now include preserving, canning and the most important of all freezing with sugar or syrup (21).

For desirable freezing preservation, a strawberry should have a pleasing potent flavor and acidity which should be retained during a long period of freezing storage. The berries should be of uniformly good size and of firm texture. On thawing, the berries should not collapse badly or lose a large quantity of juice as leakage. Berries frozen in large containers which may be used for preserve manufacture, should remain plump and not break or mush up during cooking with sugar (30).

The Marshall strawberry possesses most of the requirements for freezing and is considered to be the best variety used for freezing in this country (30). It is the most widely grown variety among the strawberries in the Pacific Northwest. It originated in Massachusetts and it was introduced into Oregon in 1890. Sometimes it is known under other names such as Oregon, Banner, Oregon Plum, Pacific, and Dewey. It serves as the standard by which all other varieties are now judged in Oregon (31).

In commercial practice, the strawberry is packed with sugar or syrup to improve its flavor and to protect it against oxidation due to contact with air. The desired amount of sugar to be added is set by the sugar and acid present in the product. When the sugar and acid content of the specific variety is known, then the processor can readily adjust the sugar and acid ratio to any desired value. This is a quality advantage as well as an economical one.

This investigation was undertaken to study the relationship of sugar and acid present in the Marshall strawberry because this relationship is very important in the commercial freezing of this fruit. The specific problem consists of

1) the determination of the content of total sugar and total acidity in frozen Marshall strawberries.
2) the determination of soluble solids and pH value.
3) the investigation of the relationship between sugar and acid.
4) the comparison of the soluble solids content with the total sugar content.

The fourth problem was brought under this study because chemical analysis for sugar in the laboratory is time-consuming and highly technical and may not be desirable in commercial practice. Since the soluble solids can be determined quickly and accurately by the hand refractometer it is advisable to check the correlation between the total sugar and the soluble solids.

II Literature Review

In judging the quality of strawberries that are best for freezing preservation, many factors; such as color, texture, freedom from defects, sugar and acid content, and astringency should be taken into consideration. It should be noted that color and texture are important in the frozen berries after thawing as well as in the fresh fruit. Schrader and Scott (25) stated that the varieties and sections which appeared to be useful for freezing are based on fresh eating quality, the red color of the flesh, and the firmness of the flesh. Culpepper, Caldwell and Moon (7) had the same point of view when they stated that the standard quality applied to commercial berries is based upon the appeal that the fruit makes when eaten in the fresh condition and sweetness is a primary consideration. Here, in considering acidity Robinson _et al_ (22) suggested that sub-acid to acid in flavor can be adapted for freezing.

In the process of freezing preservation considerable quantities of sugar are added to the fruit in the form of dry sugar or syrup. The resulting interchange with the tissue fluids of the fruit brings the change in the flavor of the fruit insofar as the balance between the sugar and acids is concerned (7). To have a balance between the sugars and the acids, the percentage of total sugar and acid present should be determined before the desired amount of sugar or syrup is added.

The content of total sugar and total acid varies with different stages of maturity. Culpepper, Caldwell, and Moon (7) observed that for young fruit, the titratable acidity generally is quite high and the total sugar content is relatively low. Free reducing sugar in most cases makes up 60 to 90 per cent of the total sugar content. At the stage of whitening, total sugar increases markedly, titratable acidity increases up to maximum point from which it declines rather rapidly. During the ripening stage, total sugar increases and the reducing sugar comprises 80 to 90 per cent of the total sugar present. Titratable acidity decreases rapidly. Nelson (18) reported the acids of the strawberry consisted of a mixture of about 10 per cent of malic acid and 90 per cent of citric acid. Consequently for the strawberry, the total acidity is calculated and reported as percent citric acid.

The sugar and acid content of strawberries are affected by the weather and growing conditions. Schuphan (26) stated that warm weather produced berries with high sugar, and moderate acid content. Bad and rainy weather and low temperatures produced berries with low sugar and high acid content. Kudryavtseva (14) pointed out also that an abundance of rain increases the moisture content and decreases the total sugar content of the strawberry. Dry weather causes a decrease in the moisture content and an increase in the sugar content. Culpepper, Caldwell, and Moon (7) explained this phenomena as follows: during a period of deficient moisture supply and favorable conditions for photosynthetic activity, the growing fruit would show a rise in sugar content; under the opposite conditions a decrease would occur. Consequently the composition of the fruit as regards sugar and acid content at any point in the period of rapid growth is determined by the rate at which absorption of water is occuring in its relation to the rates of photosynthesis and respiration.

It seems that a correlation between sugar and acid content can be expected because as fruit ripens the total sugar increases and the total acid decreases. However, the results obtained by Culpepper, Caldwell, and Moon (7) showed no indication of correlation. He explained that this absence of correlation must mean that some factor not accounted for affects one of these constituents without affecting the other. Such factors may be environmental ones.

Determination of Reducing Sugar

Carbohydrates are aldehyde or ketone derivatives of polydyric alcohols and usually the molecule contains one carboxyl and one or more hydroxyl groups, which are present in the free state in simple monosaccarides. The principal chemical method for determining sugar are based upon the property, which all aldehyde and ketone have, of reducing alkaline solutions of certain metallic salts. The higher sugars and non-sugar reserves must be hydrolyzed to free the carboxyl groups before their determination can be made (10, 12). This is accomplished either by enzyme hydrolysis or by acid hydrolysis.

In the preparation of plant extracts, for sugar analysis, clarification is necessary for the removal of non-sugar-reducing substances to avoid the interference of reduction by these substances. Saywell and Philips (24) reported that a solution of invert sugar analyzed by the copper reduction and iodine method is most satisfactorily clarified by neutral lead acetate and sodium oxalate. Other clarifying agents, such as neutral and sodium lead acetate and potassium oxalate, produce satisfactory clarification.

One of the most widely used methods for the determination of reducing sugar is the use of Fehling's solution. Fehling in 1848 first worked out this process by employing the copper sulfate and alkaline tartrate reagents (5, p.745). Henceforth many modifications have been developed by many investigators to apply to a particular need. Woodman (34) stated when Fehling's solution is used, the percentage of sugar can be estimated either 1) by determining the volume of sugar solution required to precipitate a measured amount of the copper solution, or 2) by weighing or otherwise determining the cuprous oxide reduced from an excess of the copper reagent by a measured quantity of the sugar solution.

In volumetric analysis the most common method used is Lane and Eynon's method (5, p.753). This method is based on the fact that Fehling's solution is reduced and completely decolorized by minute amounts of reducing sugar, as long as any cupric salt is absent. The methylene blue is used as the inside indicator. It is a short and rapid method for the determination of reducing sugar.

One of the official methods of the Association of Official Agricultural Chemists used for gravimetric analysis is the Allihn method (1, p.512). In addition to the reduction of cupric oxide to cuprous oxide, it involves the further reduction of the cuprous oxide to metallic copper after it has been treated with Fehling's solution. However, this method can be used only for the determination of glucose. Leach (16) expressed his view that personally he prefers the O'sullivan method because of its comparative simplicity and one can determine maltose and lactose as well as glucose.

The most common gravimetric method used today is the Munson and Walker (1, p.506) method. The copper reagent used in this method is the Soxhlet modification of the Fehling reagent. The resulting material is weighed as cuprous oxide. Hassid (11) states that this method gives satisfactory results only when the sample contains a large amount of sugar. The Committee on Methods of Chemical Analysis of the American Society of Plant Physiologists (6) referring to these methods states, "as a general rule, reduction giving less than 20 milligrams of copper should not be weighed directly, and even at this figure the percentage of error is high". Jacobs (13) states that if the precipitate in the Munson and Walker method is contaminated in any way, it is best to determine the amount of copper by dissolving the cuprous oxide in nitric acid and then by finishing the analysis with the iodo-thiosulfate method.

Shaffer and Hartman (28) reported that after heating Fehling's solution or a similar alkaline copper solution with a reducing sugar, the solution contained the oxidation products of the sugar, an excess of the cupric salt and the suspended cuprous oxide. These last two products can be determined by means of the iodometric titration. In the case of cupric salt it is completely converted into cuprous iodide with the liberation of an equivalent amount of iodine. In the case of cuprous salt it is completely oxidized to cupric salt in the presence of a known excess of iodine with the conversion of the corresponding amount of iodine into iodide. The iodine formed from iodide in the first case, and the excess iodine left in the second case, are determined by titration with standard thiosulfate, starch being used as the indicator. They stated further that this method has been applied to the determination of small quantities of sugar present in a sample.

For the determination of a small amount of reducing sugar present in a sample, Hagedorn-Jensen (12) added alkaline potassium ferricyanide to a solution of the reducing sugar and the excess ferricyanide was determined by the iodine-thiosulfate titration. The amount of ferricyanide reduced by the sugar is obtained by difference. However, this method required very careful manipulation. Whitemoyer (32) employed a modification of the ferricyanide method. The ferrocyanide which formed in the solution, is titrated with a standard solution of ceric sulfate after acidifying with sulfuric acid. Alphazurine is used as the inside indicator. He claimed that this direct method required no great skill in manipulation.

Best and Peterson (3) applied a similar principle for the determination of cuprous oxide through the reduction of ferric ammonium sulfate with subsequent titration of the ferrous ion with ceric sulfate. They concluded that this method gives a sharp end point with the O-phenanthroline ferrous complex as the indicator and the ceric sulfate solution is very stable offering no interference with the indicator.

For the determination of a very small amount of reducing sugar Shaffer-Somogyi's method (9) has been modified in various laboratories for the routine analysis of reducing sugar in biological products. Somogyi (29) points out that the copper reagent used here is more specific than the ferricyanide solution used in the Hagedorn-Jensen method. It means that the ferricyanide solution oxidizes substances other than sugar to a greater extent than the cupric ion. Another important advantage of this method is the elimination of the reoxidation of cuprous oxide by introducing sodium carbonate into the reagent. From the standpoint of determining minute amounts of reducing sugar this reoxidation action affects appreciably the accuracy and reproducibility of the results. Heinze and Murneek (12) compared the accuracy and efficiency of several common methods used in the determination of carbohydrates. They concluded that Shaffer-Somogyi's method is accurate and convenient.

Forsee (8) reported the estimation of glucose by measuring the change in color of the yellow ferricyanide solution to colorless ferrocyanide solution when an excess of alkaline ferricyanide solution is heated with the solution containing the reducing sugar. The reduction in color is proportional to the quantity of sugar present. This color decrease is measured then quantitatively in a photoelectric colorimeter. A standard curve relating reducing sugar concentration to the reading for the colorimeter is prepared for routine use. He claimed that this method is rapid and accurate, and that the procedure is simple (17).

Later Benham and Despaul (2) applied the molybdenum blue reaction for the direct colorimetric determination of glucose. This method involves the formation of a heteropoly complex with molybdate and phosphate, and its subsequent reduction to molybdenum blue upon heating with the solution of the reducing sugar. The intensity of the color increased with heating time. This method is suitable for the determination of glucose in the presence of moderate amounts of sucrose and other di-and tri-saccharrides.

Nelson (19) adapted Somogyi's reagent with added arsenomolybdate reagent for the photometric determination of glucose. This method is carried out by the omission of the iodide and iodate in the reagent. The presence of these chemicals interferes with the development of color by the molybdate reagent. He pointed out also that this method gave satisfactory stability and reproducibility of the color and it can be used in a photometric procedure for practically all the uses for which the trimetric procedure is adapted.

Determination of Titratable Acidity

The most common methods applied for the determination of titratable acidity are the two methods described by the Association of Official Agricultural Chemists (1, pp.328-329). One of these methods is based on the neutralization of the acid present in the sample with 0.1 normal alkali using phenolphthalein as the indicator. The other method employed the glass electrode for the titration of the prepared solution of the sample with 0.1 normal alkali to a desired pH value without adding an indicator.

Bollinger (4) suggested that the juice be titrated to pH 8.1 in order that the end point would agree closely with the end point in the phenolphthalein titration. Pederson and Beattle (20) used different pH values as the end point of the titration and they concluded that if the titration is completed before or beyond pH 8.1 one might attain a slight variation in the value for titratable acidity.

III Experimental Procedures

Description of the Frozen Marshall Strawberry Samples

During the 1949 strawberry season, which lasted from May 15 to July 15, samples of Marshall strawberries were collected from different freezing plants located in the states of Oregon and Washington. The samples were collected from the sorting belts just before the final packing. For the present investigation whole berries were packed in one-pound containers and frozen without the addition of sugar. All the samples were frozen and stored at 0° F for about nine months.

Preparation of the Strawberry Samples

The samples were removed from the 0° F room and kept over night at 34° F. After 15 to 20 hours, the samples were allowed to thaw out at room temperature. Other methods of thawing at higher temperature were tried but the thawed product became rather soft and mushy. When the berries were thawed at lower temperatures, they were very firm and the product was much more satisfactory. Thawing at low temperatures was adopted for the present investigation.

After the samples were thawed a puree of 150 grams of the sample was prepared by using the RYP juicer. It runs at a speed of 5000 r.p.m. and operates on the same principle as a centrifuge, whereby all seeds are practically removed and the puree so obtained is uniform and consistent in character. It was observed during the investigation that when the samples of the same weight were taken, the final weight of the puree remained practically the same in all cases.

Puree was prepared also by using a Waring blender and a copper screen. The Waring blender incorporates much air and the seeds are not removed by this procedure, which produced variable results. The copper screen is responsible for changes in the color of strawberries due to catalytic oxidation of the anthocyanin pigments. Thus, puree prepared by the RYP juicer was the most satisfactory for the present investigation (27).

Determination of Reducing Sugar

The method used for the determination of reducing sugar was based upon a modification of Shaffer and Somogyi's method (9). The amount of reducing sugar found in the unknown sugar solution was calculated as the percentage of glucose present in the sample.

Twenty grams of puree prepared with the puree machine were weighed and then washed into a 500 ml. volumetric flask with distilled water. It was made up to volume and shaken thoroughly for a few minutes. A 50 ml. aliquot was pippetted into a 100 ml. beaker, then clarified with neutral lead acetate solution (2). After the clarification was complete, the solution was transferred into a 100 ml. volumetric flask and made up to the mark. A 5 ml. aliquot of the test solution was pippetted from the 100 ml. volumetric flask into a 25 x 100 m.m. Pyrex test tube and mixed thoroughly with 5 ml. of the sugar reagents which were previously prepared as directed by Fulmer et al (9). The tube was fitted with a rubber stopper provided with a short piece of capillary tubing. The tube was immersed then in a boiling water bath and heated for 30 minutes as previously determined (see Figure 2 on page 16). The contents of the tube were cooled by running water, 2 ml. of the potassium iodine-oxalate solution were added, and the solution was mixed thoroughly by shaking. To this mixture 1 ml. of the 7.5 normal sulfuric acid was added carefully and mixed by slowly revolving the test tube until the first violent evolution of carbon dioxide had subsided; then the solution was mixed thoroughly by shaking. Sufficient time was allowed for all the cuprous oxide to dissolve. The excess iodine is titrated finally with the standard sodium thiosulfate solution using the starch indicator near the end point. A blank was run in exactly the same manner using 5 ml. of water as the test sample. The difference, corresponding to the volume of standard thiosulfate solution consumed by the cupous oxide is converted into milligrams of sugar per 5 ml. of solution by reading from the standard curve in Figure 1. Then the milligrams of sugar found are converted to the percentage of reducing sugar in the strawberry sample.

Method for Inversion

Fifty ml. of the clarified solution was pippetted into a 100 ml. volumetric flask and neutralized with dilute hydrochloric acid. Then 10 ml. of HCl (Sp. Gr. 1.1029) was added and set aside for 24 hours at a temperature not below 20° C (1, p.503). When the conversion was completed, the sample was transferred into a 100 ml. beaker and neutralized with sodium carbonate using bromothymol blue as the indicator. Bromothymol blue has a pH range of 6 to 7.6. In the presence

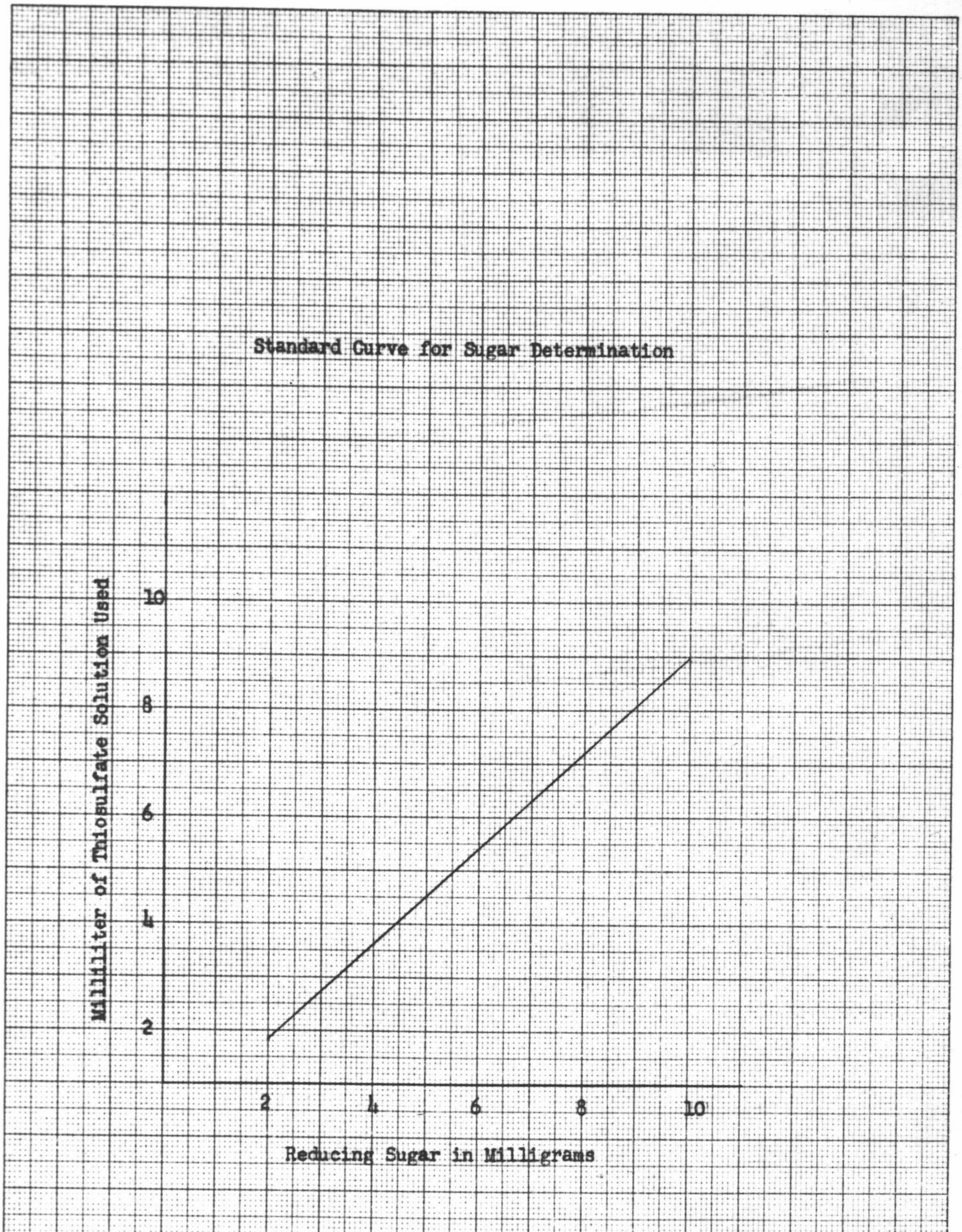
Standard Curve for Sugar Determination
Milliliter of Thiosulfate Solution Used
10
8
6
4
2
2
4
6
8
10
Reducing Sugar in Milligrams

Figure 1

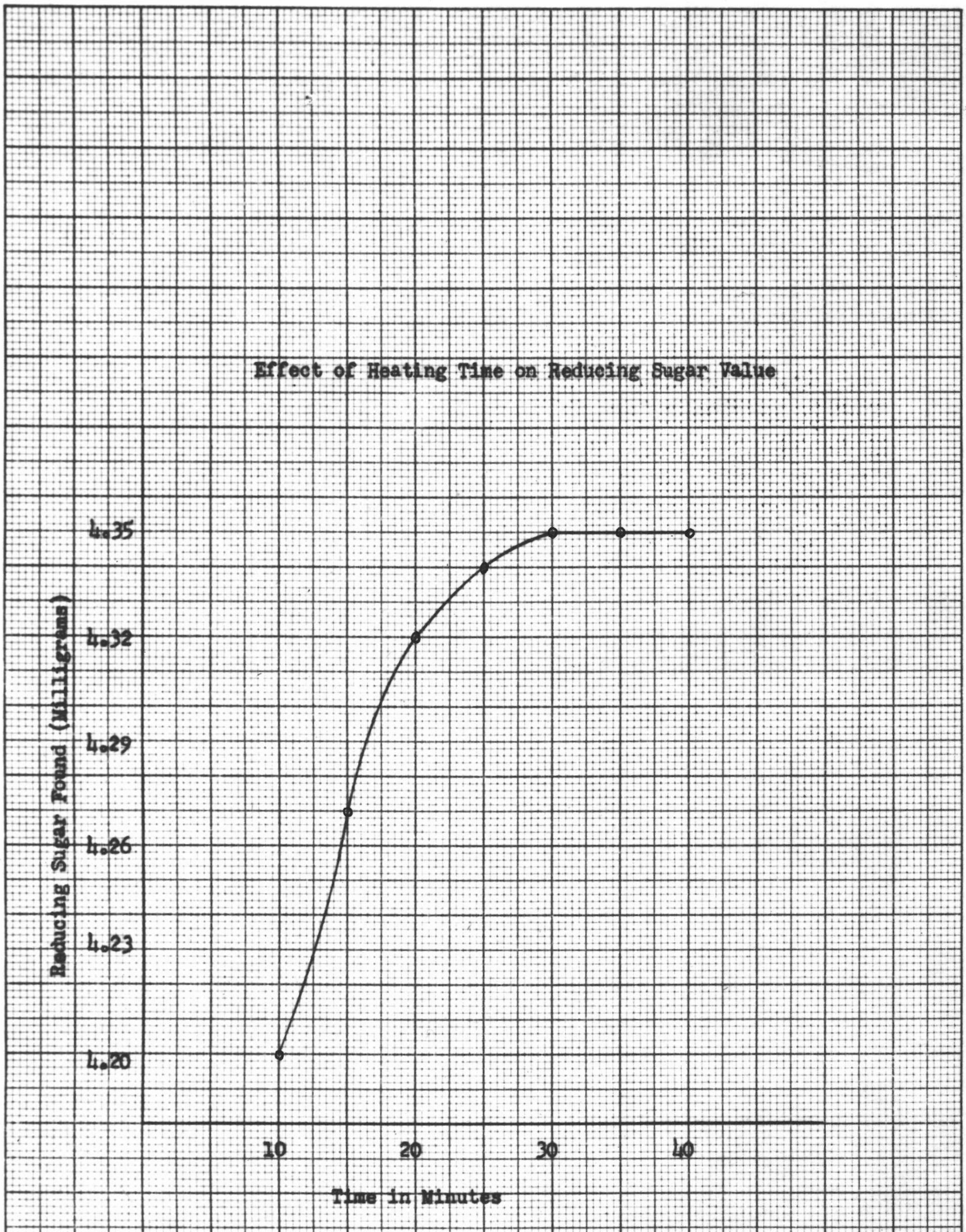
Effect of Heating Time on Reducing Sugar Value
Reducing Sugar Found (Milligrams)
4.35
4.32
4.29
4.26
4.23
4.20
10
20
30
40
Time in Minutes

Figure 2

of acid solution it turns yellow and in basic solution it turns blue. The solution was transferred back into the 100 ml. volumetric flask and made up to volume. Then the sample was analyzed by the same method as for the reducing sugar.

Determination of Titratable Acidity

The titration method, based on that described by the Association of Official Agricultural Chemists (1, p.329) was used in determining the titratable acidity of the strawberry. Ten grams of strawberry puree were weighed and diluted with freshly boiled water in a 250 ml. beaker. Then the diluted sample was titrated with sodium hydroxide of 0.0983 normal, using the glass electrode of a Beckman pH meter to determine the end point for the titration. The end point of the titration is at pH 8.1 ± 0.2. The final acidity was calculated as the percentage of citric acid present in the sample.

Determination of Soluble Solids

The Bausch and Lomb hand refractometer was the instrument used in this investigation. The procedure for the determination is based on that described by the Association of Official Agricultural Chemists (1, p.429). The puree after thawing from the frozen state was stirred thoroughly to obtain a uniform sample. One drop of the sample is placed on the surface of the lower prism. Close the prism and let it stand for 4 to 5 minutes before the reading is taken. Care should be taken to avoid any contacts of the fingers with the thermometer attached to the side of the refractometer. This thermometer is provided for the temperature correction and any contacts with the hands or fingers will influence the temperature, and thus affect the accuracy of the reading.

IV Results and Discussion

The standard curve showing the relation between the volume of standard sodium thiosulfate solution and the milligrams of reducing sugar is illustrated in Figure 1. All the strawberry samples fell within the range shown in Table I.

Table I

Relation Between the Volume of Standard Thiosulfate Used and the Reducing Sugar Value

Glucose in Milligrams*	ml. of Thiosulfate Solution**
2	1.82
4	3.57
6	5.38
8	7.18
10	9.96

* Value for 5 ml. of the sugar-containing solution.

** Sodium thiosulfate solution is 0.0525 N.

The effect of heating the solution for various periods of time in relation to the milligrams of reducing sugar found is illustrated in Figure 2.

This discussion of results is confined to the samples of Marshall strawberries processed during the 1949 season. The data for soluble solids, pH of the fruit, total sugar, total acidity, and sugar-acid ratio are tabulated in Table II.

Variations in total sugar, total acid, and soluble solids in these values will be affected by the composition of the soil, weather and processing conditions. Rain during part of the harvest season would affect adversely the sugar and soluble solids contents of the berries picked immediately after the rainy spell. Some processing plants leave more moisture on the berries than other plants do. Strawberries picked early in the season and picked later in the season exhibit differences. Generally, berries picked early in the season are low in sugar (Figure 4). Immature berries may be included in the early pickings.

For the samples analyzed the average sugar content of the Marshall strawberry in the Pacific Northwest is 7.56 per cent. This value is higher than the value, 5.00, reported for varieties grown in the east (7). On the other hand, the average acidity in this area is 0.98 per cent which is considered in the medium range for total acidity.

For the samples analyzed the soluble solids averaged 9.90 per cent. This is higher than the average value, 6.98, per cent calculated from Robinson's data (22) for strawberries of many varieties

Table II

Analytical Data for Frozen Marshall Strawberries

Code No.	*Date	Soluble Solids	**pH value	Total Sugar	Total Acidity	Sugar-acid Ratio
6 A	5/30	7.90	3.35	5.50	0.74	6.7
8	"	8.20	3.30	6.74	0.94	7.10
45 F	5/31	10.00	3.42	8.10	0.99	8.20
28 A	6/1	8.50	3.20	6.54	0.82	8.0
42	2	9.50	3.29	7.25	1.08	6.7
48 B	2	10.75	3.33	8.23	1.10	7.5
11 E	3	8.25	3.40	5.36	0.98	5.5
32 G	3	10.00	3.26	7.65	1.14	7.00
12 W	4	8.80	3.26	5.94	0.97	6.10
111 W	4	9.25	3.22	7.15	1.05	6.80
49 C	6	8.00	3.34	5.83	0.94	6.20
39 C	7	8.25	3.33	6.36	0.93	6.80
35 E	7	8.25	3.36	6.30	0.82	7.70
105	9	10.25	3.34	8.43	1.00	8.40
26	9	9.50	3.41	7.23	1.08	6.70
25 A	9	10.50	3.42	7.58	0.86	8.80
46 C	10	9.00	3.26	6.57	1.16	5.70
7 E	10	8.75	3.30	7.05	0.93	7.60
19 C	10	10.00	3.45	7.01	0.85	9.40
20 C	10	8.50	3.31	6.40	0.90	7.10
9	11	9.50	3.43	7.98	0.92	8.70
17 G	11	9.75	3.40	7.54	0.83	9.10

Table II (Cont.)

Code No.	*Date	Soluble Solids	**pH value	Total Sugar	Total Acidity	Sugar-acid Ratio
10 D	11	9.25	3.39	5.36	1.02	5.30
18 D	11	8.50	3.34	5.24	0.99	5.20
36 F	13	10.40	3.46	8.25	0.85	9.70
120	13	10.50	3.22	7.65	0.97	7.90
122 F	13	9.75	3.22	7.42	0.80	9.30
38 A	14	10.60	3.40	8.48	0.87	9.70
41	14	10.10	3.52	8.14	0.88	9.20
109	14	9.60	3.47	7.52	0.97	7.80
43 G	15	11.25	3.45	8.73	1.12	7.80
27 G	15	11.00	3.43	8.78	1.07	8.20
22 B	16	11.75	3.40	9.06	1.01	9.00
24	16	10.25	3.36	7.67	1.02	7.50
40	16	9.25	3.42	7.05	0.93	7.60
16 E	16	12.20	3.30	9.50	0.98	9.70
21 B	16	11.75	3.40	9.35	1.12	8.40
33 B	16	12.25	3.46	9.78	1.16	8.40
103 B	16	11.25	3.40	9.17	1.10	8.30
31	17	10.90	3.49	8.33	0.95	8.70
16 D	19	10.50	3.30	8.46	1.06	9.10
34 D	19	11.50	3.48	8.41	1.09	7.70
44	22	11.25	3.32	8.64	1.09	7.90
47 F	25	11.00	3.62	8.89	1.01	8.90

* This date refers to the processing time.

** These values were determined by Shah (27).

grown in New York State. Sugar, acid and soluble solids distributions are illustrated in Figure 3. In spite of the variations the total sugar tends to concentrate in the range from 7.1 to 8.0 per cent and the total acid in the range from 0.91 to 1.0 per cent, respectively. The total acidity showed a tendency to be distributed more at a higher concentration than at a lower one. This may be an indication that the decrease in total acidity at prime maturity is only very slight. Soluble solids concentrated in the range from 9.10 to 11.0 per cent.

The definite relationship between the soluble solids and total sugar content is shown in Figure 5. An increase in the soluble solids was paralleled by an increase in the total sugar content of the strawberries. On the average, the soluble solids has a value 2.34 units higher than the total sugar content. For the strawberries analyzed, a rough approximation for the total sugar would be quickly determined by subtracting 2.34 from the value for the soluble solids. Whether this figure would be applicable for Marshall strawberries taken off the sorting belt during any processing season, could be determined only by checking many more samples for at least several additional seasons.

As the fruit became more mature the sugar content increased (7). Results illustrated in Figure 4 indicates that the Marshall strawberry grown in the Pacific Northwest follows this same pattern. However, certain variations in total sugar content are very noticeable in Figure 4. The low values may be due to short periods of rainy weather or they may reflect varying processing conditions in the different freezing plants. Failure to remove surplus water from the berries after

The Distribution of Total Acid, Total Sugar, and Soluble Solids in the Marshall Strawberry

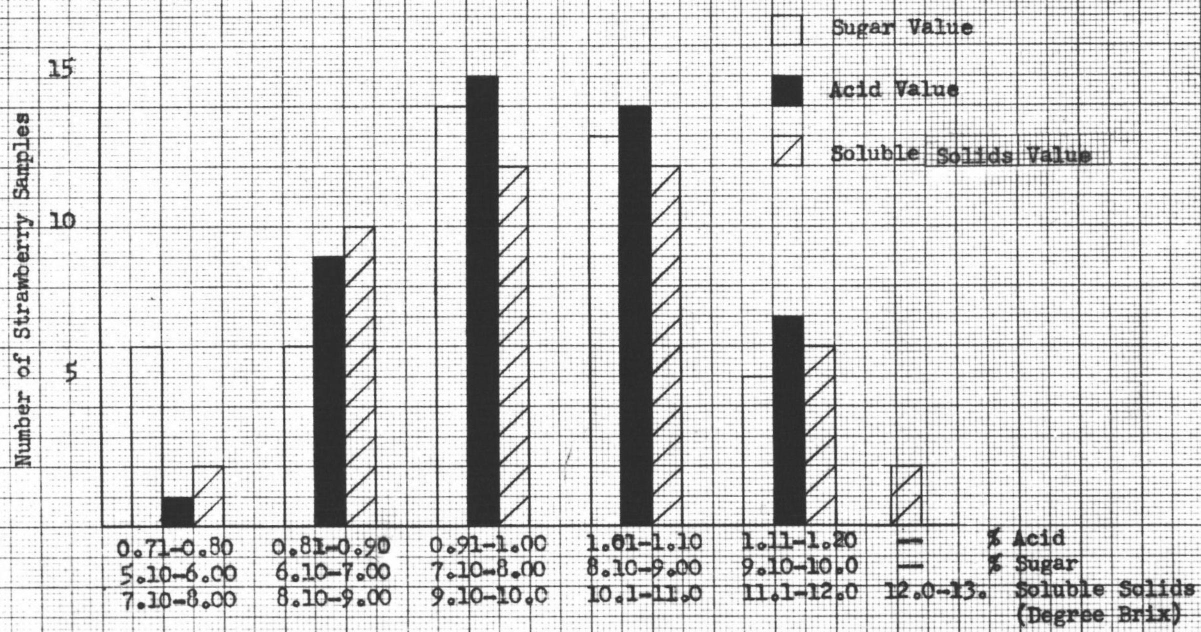

Figure 3

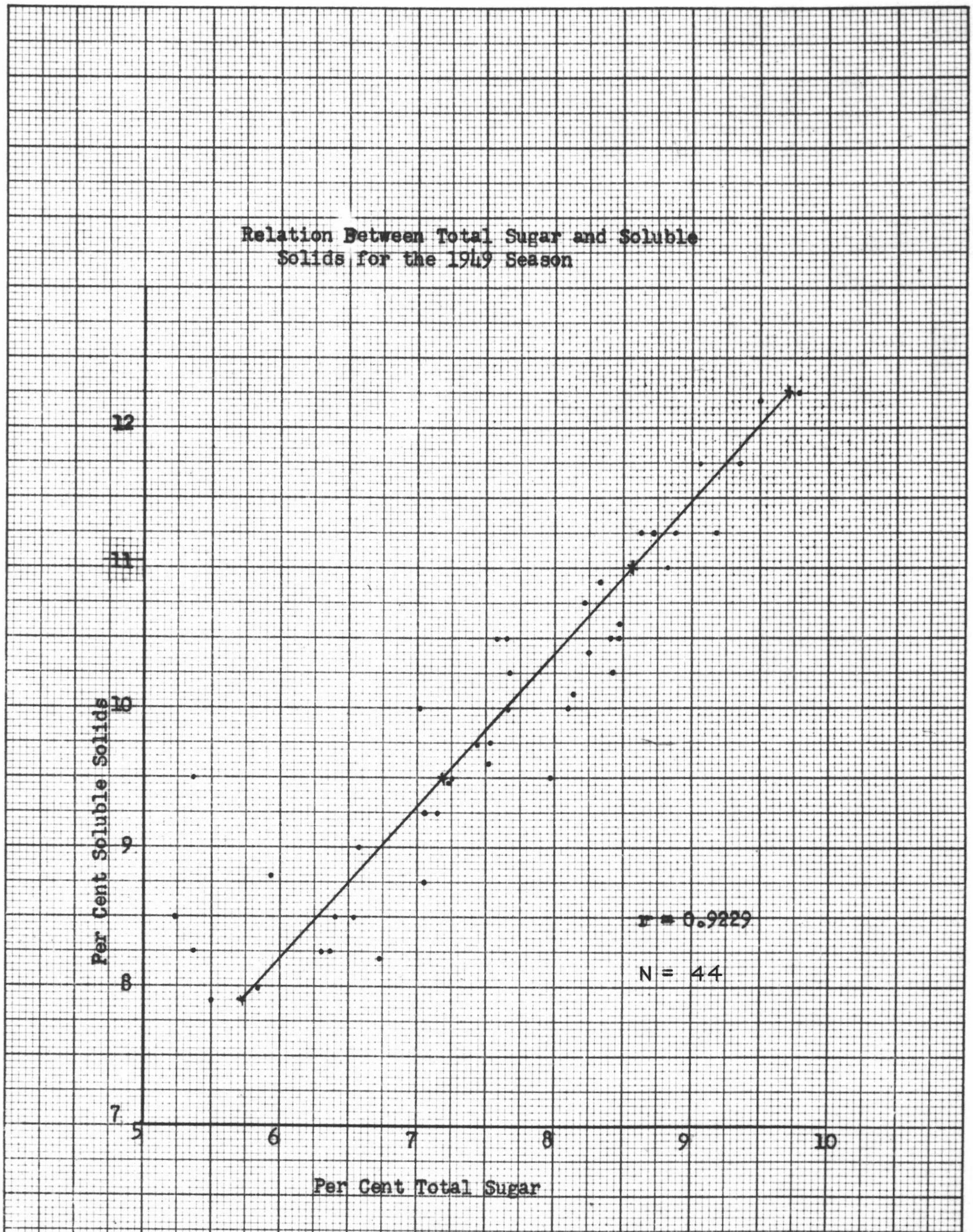
Relation Between Total Sugar and Soluble Solids for the 1949 Season
Per Cent Soluble Solids
12
11
10
9
8
7
5
6
7
8
9
10
r = 0.9229
N = 44
Per Cent Total Sugar

Figure 5

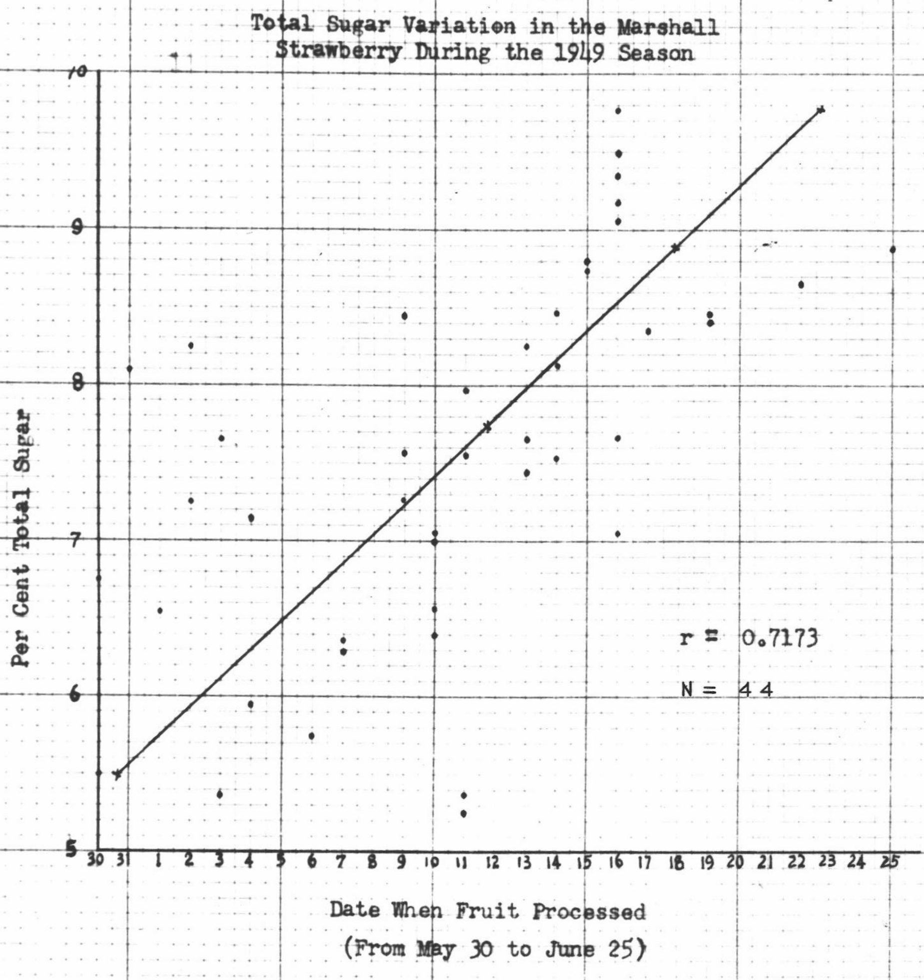
Total Sugar Variation in the Marshall Strawberry During the 1949 Season
Per Cent Total Sugar
10
9
8
7
6
5
30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
r = 0.7173
N = 44
Date When Fruit Processed
(From May 30 to June 25)

Figure 4

washing would produce berries of lower percentage sugar values on analysis. Of course, these two conditions might not be affecting a particular sample, and this strawberry sample might be normally low in total sugar content. On the other hand, some of the strawberries were very high in sugar content. The values found in these samples for total acidity showed great variation. There is no correlation between total acidity and date of processing. There is no correlation between sugar and acid content. This agrees with the work of Culpepper, Caldwell, and Moon (7). They explained the absence of correlation between sugar and acid content as due to an environmental factor.

Marshall strawberries grown in different areas in the Pacific Northwest have different total sugar and acid contents. These values for various areas in Oregon are tabulated in Table III. The classification of the sugar and acid content is shown in Table IV. This classification was based upon the average figure given in Table V. The classification ranges are as follows:

	High	Medium	Low
Sugar	above 8.0%	7.0-8.0%	below 7.0%
Acid	above 1.0%	0.9-1.0%	below 0.9%

The strawberries from the Forest Grove and Woodburn areas have a high sugar content which may be due to the warm valley weather. Strawberries from the Cottrell and Banks areas showed low sugar content because these berries were grown mainly in sandy soil on hillsides where cooler temperatures prevail. Generally, berries from warmer areas are more mature and show a higher sugar content than those grown on hillsides. This agrees with the results of the Russian investigator, Kudryavtseva (14) and the German investigator Schuphan (26).

Table III

Analytical Data for Frozen Marshall Strawberries
From Different Areas of Oregon

Packing Company	Code No.	Soluble Solids	Total Sugar	Total Acidity
A				
	6 A	7.90	5.50	0.74
	28 A	8.50	6.54	0.82
	25 A	10.50	7.58	0.86
	38 A	10.60	8.48	0.87
	Average	9.37	7.02	0.82
B				
	48 B	10.75	8.23	1.10
	21 B	11.75	9.35	1.12
	22 B	11.75	9.06	1.01
	103 B	11.25	9.17	1.10
	33 B	12.25	9.78	1.16
	Average	11.55	9.11	1.09
C				
	49 C	8.00	5.83	0.94
	39 C	8.25	6.36	0.93
	46 C	9.00	6.57	1.16
	19 C	10.00	7.01	0.85
	20 C	8.50	6.40	0.90
	Average	8.75	6.43	0.95
D				
	18 D	8.50	5.24	0.99
	10 D	9.25	5.36	1.02
	34 D	11.50	8.41	1.09
	16 D	10.50	8.46	1.06
	Average	9.93	6.86	1.04
E				
	35 E	8.25	6.30	0.82
	11 E	8.25	5.36	0.98
	7 E	8.75	7.05	0.93
	16 E	12.20	9.50	0.98
	Average	9.61	7.05	0.92
F				
	36 F	10.40	8.25	0.85
	122 F	9.75	7.42	0.80
	45 F	10.00	8.10	0.99
	47 F	11.00	8.89	1.01
	Average	10.28	8.16	0.91
G				
	32 G	10.00	7.65	1.14
	17 G	9.75	7.54	0.83
	43 G	11.25	8.73	1.12
	27 G	11.00	8.78	1.07
	Average	10.50	8.17	1.04

Table IV

Variation in the Sugar and Acid Content of Marshall Strawberries From Different Areas in Oregon

Packing Company	Source of Berries	Sugar Content	Acid Content
A	Stayton area	Medium	Low
B	Forest Grove area	High	High
C	Gresham area	Low	Medium
D	Banks area	Low	High
E	Cottrell area	Low	Medium
F	Woodburn area	High	Medium
	Forest Grove area	High	Medium
G	Gresham area	High	High

Table V

Variation in the Analytical Data for Frozen Marshall Strawberries*

	Maximum Reading	Minimum Reading	Average	Standard Deviation
Soluble Solids	12.20	8.00	9.90	± 1.18
pH Value	3.62	3.20	3.36	± 0.09
Total Sugar	9.78	5.24	7.56	± 1.18
Total Acidity	1.16	0.74	0.98	± 0.10
Sugar-Acid Ratio	9.70	5.20	7.80	± 1.20

*This data based on analysis of 44 samples of Marshall strawberries.

V Summary

Marshall strawberries frozen (no sugar added) in commercial plants during the 1949 season were analyzed for soluble solids, pH of the fruit, total sugar, and total acidity.

Soluble solids determined by the hand refractometer had an average value of 9.90 per cent. The average pH value for all samples was 3.36. Total sugar averaged 7.56 per cent for all samples analyzed. The total acidity determined by direct titration with the glass electrode showed an average value of 0.99 per cent. The sugar-acid ratio had an average value of 7.8.

The sugar and acid content of these Marshall strawberries showed most frequent distribution in the range from 7.1 to 8.0 per cent and 0.91 and 1.0 per cent, respectively. Soluble solids were most frequent in the range from 9.10 to 11.0 per cent.

No relationship was found for total sugar and acid content. Soluble solids were found to have a definite relationship with total sugar. Marshall strawberries grown in different areas of Oregon varied in total sugar and acid content. Based on average values of the samples tested, sugar and acid content were classified into high, medium and low ranges. Generally, strawberries grown in warm areas and mature berries tend to have a higher sugar content. Berries grown on the hillsides and less mature berries tend to have a lower sugar content.

The weather condition apparently has a great effect on the sugar and acid content of strawberries. The data obtained in this study represents information from the 1949 season.

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