OBJECTIVE DETERMINATION FOR CONSISTENCY OF TOMATO JUICE

by

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OBJECTIVE DETERMINATION FOR CONSISTENCY OF TOMATO JUICE

I. INTRODUCTION

Tomato juice, now accepted as an item in everyday food, started its industry in a small way in 1928; it was almost instantly successful, reaching in 1930 a production of 1,338,964 cases (equivalent cases of 24 No. 2 cans). Except for a slight decline in 1933, the industry has grown steadily and rapidly. In 1937 the annual production passed 13,000,000 cases. The United States Department of Agriculture reported that 26,180,000 cases of tomato juice were packed in 1950. Between 1941 and 1950 the annual production averaged 25,251,000 cases (9, p.271).

In 1930 the industry was located almost entirely in the East. Since 1931 California has produced large quantities of tomato juice and is now one of the leading states in this respect. Indiana, New Jersey, Maryland, New York, Pennsylvania and Ohio also produce large quantities of tomato juice. A small amount of tomato juice is produced in Utah, Texas, Washington, Oregon and other states.

Leading varieties of tomatoes suitable for juice manufacturing are John Bear, Marglobe, Nystate, Rutgers, Pritchard, Supreme, Early Baltimore and Landreth. In California the Norton, Alameda Trophy and the Santa Clara Canner varieties are used (8, p.307).

The Oregon State Agricultural Experiment Station has grown several new varieties of tomatoes in 1952. The purpose of this investigation is to evaluate objectively one quality factor, consistency, of tomato juice manufactured under standard conditions from these tomatoes.

Color, flavor and consistency are the three main factors which determine the quality of tomato juice. As with other tomato products such as tomato puree, tomato paste, etc., the United States Department of Agriculture through its Production and Marketing Administration, has available for voluntary use United States Standards for Grades of Tomato Juice (2, p.51). The grades are based on a scoring system, the relative importance of each element has been expressed numerically on a scale of 100. The maximum number of points that may be given for each factor is:

Color	30
Consistency	15
Absence of Defects	15
Flavor	40
Total	100

In recent years, a great deal of work has been done on the color evaluation of tomato juice, and research has been greatly accelerated in this field since the introduction of the Hunter Color Difference Meter. Flavor would entail a complex study and is beyond the scope of this investigation. Very little research has been done on the consistency of tomato juice, especially in this part of the country; consequently, it is our objective to investigate the factor of consistency in tomato juice.

II. REVIEW OF LITERATURE

Bingham (3) stated that consistency is that property of a material by which it resists permanent change of shape and is defined by the complete flow-force relation. If in non-turbulent flow, the ratio of flow to force is constant, the material is said to be fluid; otherwise it is plastic. Viscosity is the measure of the resistance to continuous deformation in a fluid.

A review of literature reveals that very little work has been done on the consistency of tomato juice. Consistency has been referred to as viscosity by Production and Marketing Administration (10, p.4) in their grade standards for tomato juice. Their method of grading is rather subjective as may be seen in their descriptions.

"(A) Fancy grade: Tomato juice that possesses a good consistency, flowing readily, and showing very little or no tendency to separate, may be given a credit of 13 to 15 points for this factor.

(C) Standard grade: Tomato juice that possesses a fairly good consistency, but which may show some tendency to separate, may be given a credit of 10 to 12 points.

(D) Sub-standard grade: Tomato juice having poor consistency, being either too heavy or thin, or that separates rapidly, may be given a credit within the range of 0 to 9 points."

It is an almost universal practise to express the consistency of tomato juice in terms of its "gross viscosity". Kertesz and

Loconti (4, p.6) found it an inadequate index of the actual consistency of a juice. The explanation is that by a judicious balance of various factors a number of juices could have the same gross viscosities, but the character of the consistencies of the different juices may be entirely different. For example, two juices having the same gross viscosity could be composed of a very viscous serum and a small proportion of finely divided suspended particles. On the other hand, the second juice has a serum of low viscosity but contains a large portion of suspended solids. The first of these juices will possess a more desirable consistency because in addition to its viscous character it also has a pleasing smoothness. The second one, although having the same mechanically determined "gross viscosity" as the first, will feel somewhat watery and have a rough "texture". Thus, our palate can distinguish between a viscosity caused primarily by a viscous serum and one caused chiefly by the suspended solids.

This is precisely the point where viscosity determination by any of the conventional methods fail because they can not differentiate between such widely differing juices. So the consistency of a tomato juice may be characterized more precisely by the "gross viscosity" of the juice as measured by a suitable method and supplementing this information with the measurement of the viscosity of the serum.

III. EXPERIMENTAL PROCEDURES

A. Materials.

The tomatoes harvested in the field in the latter part of September, 1952, were allowed to "ripen" for 48 hours at room temperature before processing.

The hot break method was selected for the preparation of the tomato juice. The tomatoes were carefully trimmed and the cores and sun-burned yellowed portions of the tomato were discarded; then the trimmed tomatoes were heated in a steam kettle until the temperature reached 180°F with agitation to avoid scorching. The hot tomatoes were juiced by a Langsenkamp laboratory pulper model 185S with a screen size of 0.027 inches. The juice was then heated up to 180°F again and filled into No. 2 cans and sealed without salting. Of the twelve varieties canned, four varieties were processed with salt by adding one 50 grain salt tablet to each can before sealing. An equal portion of each of these four varieties was processed without salt. The canned juice was processed at 212°F for five minutes.

B. Methods of analysis.

After storage for three months at room temperature, the canned tomato juice was analyzed as follows:

1. Gross viscosity (total relative viscosity).

The Stormer viscosimeter was found (4,5,7) to be most suitable for measuring the "gross viscosity" or "total viscosity" of tomato juice. A Stormer viscosimeter model 7649 was used in each test which was carried out with 90 ml. of tomato juice at 25°C. The canned juice was warmed up to 25°C slowly in a water bath before opening. During the temperature adjustment period, shaking of the canned tomato juice was kept at a minimum because gross viscosity decreases upon vigorous shaking. The temperature was checked frequently by the opening of control samples. When the desired temperature was attained, the test samples were opened and poured into 600 ml. beakers; 90 ml. samples of tomato juice were then measured from the beakers by the use of a 100 ml. graduated cylinder. It was found that samples measured out in this way gave homogeneous consistency without vigorous shaking or stirring. Only the first reading obtained from the Stormer viscosimeter was recorded, because the gross viscosity decreases in subsequent rotations due to the shearing effect of suspended particles; however, gross viscosity will recover after setting for 30 minutes.

The value found for distilled water was 8.0 seconds at 25°C. Relative viscosity is obtained by dividing the value (time in seconds required for 100 revolutions) of tomato juice, by the value for distilled water obtained by the identical procedure at the same temperature and with the same operating weight.

2. Rate of filtration.

The rate of filtration was determined by pouring 100 ml. of tomato juice onto a No. 12 Whatman folded filter paper placed in a fluted-glass funnel. The diameter of the paper was 18.5 cm. After exactly fifteen minutes the volume of filtrate was noted. The juice temperature was about 25°C.

3. Relative viscosity of the serum.

The serum is the filtrate obtained by filtering the tomato juice through No. 12 Whatman filter paper. The Ostwald viscosimeter (6, pp.103-104) was used for the measurement of serum viscosity, because the serum viscosity is very low.

10 ml. of tomato juice serum at 25°C was introduced into the viscosimeter immersed in a constant water bath, and it was then drawn up by suction into the bulb until the liquid level was above the upper mark of the viscosimeter. The liquid was then allowed to drain, and the time necessary for the liquid to fall from upper to lower mark was measured with a stopwatch. The viscosimeter was then cleaned, and the whole operation was repeated using distilled water as the reference liquid. In this manner, the time, t_1, for tomato juice serum and the time, t_2, for distilled water were obtained, and the relative viscosity was calculated by the Poiseuille equation (6, pp.103-104).

$$\text{Relative serum viscosity} = \frac{d_1 t_1}{d_2 t_2}$$

where d_1 and d_2 were the densities of the two liquids which were determined at 25°C by use of a Brix hydrometer.

4. Volume of centrifuged solids.

100 ml. of homogenized tomato juice were poured into two 50 ml. graduated conical centrifuge tubes; then the tubes were centrifuged at about 30°C at 1400 r.p.m. for 30 minutes in a E-3 Precision Scientific Centrifuge. The volume of suspended solids in the two

tubes were measured.

5. pH value.

A Beckman pH meter model H-2 was used for this purpose. A buffer solution at pH 4 prepared by dissolving a pHydrio buffer tablet into 100 ml. of distilled water was used for the standardization.

6. Total soluble solids.

The procedure for the determination is based on that described by the Association of Official Agricultural Chemist (1, p.429). The Carl Zeiss refractometer with a scale where each division is equivalent to 0.2% was used. One drop of sample at 20°C was placed on the surface of the lower prism. The reading was taken immediately upon closing the prism.

7. P.M.A. grading.

Two cans of unsalted tomato juice of each variety were graded by Production and Marketing Administration specialists at West Salem, Oregon.

In addition to the canned tomato juice processed from the new varieties, nine different brands of commercial canned tomato juice available on the market were analyzed for relative gross viscosity, relative serum viscosity, volume of centrifuged solids and rate of filtration.

IV. RESULTS AND DISCUSSION

The results for the Stormer readings, filtration rates and calculations of relative gross viscosities are tabulated in Appendix Table 1. The water value of 8.0 seconds was used in the calculation.

The results for the Ostwald readings, density ratios of tomato juice serum vs. distilled water and calculations or relative serum viscosities are tabulated in Appendix Table 2. The average time required for the water standard of Ostwald viscosity was 105.05 seconds for a volume of 10 ml. at 25°C.

The results of the volume of centrifuged solids, total soluble solids and the pH values are tabulated in Appendix Table 3.

The results of P.M.A. grading are tabulated in Appendix Table 4.

Data obtained from commercial samples are presented in Appendix Table 5.

Of the twelve varieties of tomato juice canned, four varieties were divided into two portions, one plain and one salted. Data obtained from the salted juice can be used with data obtained from plain juice together in further statistical analysis provided that the salt treatment did not show any effect. The data from these four varieties, namely O.S.C. 31, Queen, O.S.C. 49 and Assoc. 1044 were grouped and subjected to analysis of variance to study the following effects.

1. Salting effect on gross viscosity.
2. Salting effect on serum viscosity.

3. Salting effect on rate of filtration.

Tables 1 and 3 show that these experiments are completely randomized factorial experiment with multiple replications. Only the calculation of analysis of variance for the effect of salt on relative gross viscosity is presented in detail as shown in Appendix Table 6. The results of analysis of variance are presented in Tables 2 and 4.

For the gross viscosity, pooled error mean was used because there is no interaction. At the concentration used, salt does not affect the gross viscosity since the F value = 0.2419 is not significant. These four varieties give different gross viscosities as F value = 15.5695 with 3 and 35 degrees of freedom is significant at the 5% significance level.

For the serum viscosity, both F values are significant. The interpretations of these results are that the serum viscosity of these four varieties are not the same and the salting of the juice will increase the viscosity of the juice serum. However, the increase in the value of the serum viscosity is so small that it is negligible as far as the gross viscosity is concerned.

For the rate of filtration, at the concentration used salt has no effect on the rate of filtration because the F value = 1.1337 with 1 and 3 degrees of freedom is not significant at the 5% significance level. The rates of filtration of these four varieties are not the same because the F value = 11.7855 with 3 and 3 degrees of freedom is significant at the 5% significance level.

TABLE 1

VISCOSITY VALUES

A. Relative Gross Viscosity

	O.S.C. 31	Queen	O.S.C. 49	Assoc. 1044	Total
Plain	2.600	3.588	3.475	1.900	
	2.588	3.813	5.163	1.738	
	2.438	4.775	3.975	2.288	68.305
	2.763	5.238	4.175	2.950	
	3.100	5.825	3.550	2.363	
	13.489	23.239	20.338	11.239	
Salted	3.563	3.525	4.004	3.425	
	3.500	4.588	1.763	2.050	
	2.575	4.938	2.113	1.800	65.920
	3.050	4.588	3.150	2.125	
	3.350	4.275	5.313	2.225	
	16.038	21.914	16.343	11.625	
Total	29.527	45.153	36.681	22.864	G.T. = 134.225

B. Relative Serum Viscosity

	O.S.C. 31	Queen	O.S.C. 49	Assoc. 1044
Plain	1.265	1.341	1.692	1.252
	1.260	1.339	1.714	1.230
	1.255	1.337	1.692	1.254
	1.250	1.371	1.678	1.242
	1.269	1.369	1.660	1.244
Mean	1.2598	1.3514	1.6872	1.2446
Salted	1.252	1.378	1.727	1.277
	1.263	1.367	1.717	1.254
	1.276	1.375	1.733	1.282
	1.276	1.394	1.742	1.315
	1.270	1.365	1.737	1.273
Mean	1.2674	1.3758	1.7304	1.2802

TABLE 2

ANALYSIS OF VARIANCE FOR THE EFFECT OF SALT ON VISCOSITY

A. Relative Gross Viscosity

Variation due to:	Sum of squares	Degrees of freedom	Mean square	F	Remarks*
Varieties	27.4808	3	9.1603	15.5695	significant
Treatment	0.1423	1	0.1423	0.2419	not significant
Interaction	2.2939	3	0.7646	1.337	no interaction
Error	18.2984	32	0.5718		
Total	48.2154	39			
(pooled error mean square = 0.58835 with 35 d.f.)					

B. Relative Serum Viscosity

Variation due to:	Sum of squares	Degrees of freedom	Mean square	F	Remarks*
Varieties	1.3422	3	0.4474	1841.91	significant
Treatment	0.0077	1	0.0077	31.70	significant
Interaction	0.0018	3	0.0006	2.87	no interaction
Error	0.0067	32	0.0002094		
Total	1.3584	39			
(pooled error mean square = 0.0002429 with 35 d.f.)					

* At the 5% significance level.

TABLE 3

DATA OF RATE OF FILTRATION

	O.S.C. 31	Queen	O.S.C. 49	Assoc. 1044
Plain	22.25	17.25	13.75	22.00
	22.25	18.00	14.75	22.75
	21.25	18.50	14.00	22.00
	21.75	17.75	15.00	22.75
	22.50	17.50	14.00	22.00
Mean	22.00	17.80	14.30	22.30
Salted	23.00	17.50	13.00	25.25
	23.25	17.50	15.00	25.50
	23.75	18.50	14.00	27.00
	24.25	17.50	14.00	30.00
	23.00	18.00	13.75	28.00
Mean	22.45	17.80	13.95	27.15

TABLE 4

ANALYSIS OF VARIANCE FOR THE EFFECT OF SALT ON THE RATE OF FILTRATION

Variation due to:	Sum of squares	Degrees of freedom	Mean square	F	Remarks*
Varieties	690.0923	3	230.0308	11.7855	significant
Treatment	22.127	1	22.127	1.1337	not significant
Interaction	55.5542	3	19.5181	27.1537	no interaction
Error	23.0000	32	0.7188		
Total	777.4610	39			

* At the 5% significance level.

4. Relationships between viscosities and P.M.A. grading.

From the results obtained from Tables 2 and 4, it is concluded that salting does not affect the relative gross viscosity. All data of relative gross viscosity obtained from salted juice were therefore used with data obtained from plain juice for the analysis of variance. There are 12 varieties, each with 10 observations, totaling 120 observations. The hypotheses of the test is that these 12 varieties have the same relative gross viscosity with the assumptions that the samples are random samples drawn from normal populations whose variances are the same. The result of the calculation is shown in Table 5.

TABLE 5

ANALYSIS OF VARIANCE FOR RELATIVE GROSS VISCOSITY

Variation due to:	Sum of squares	Degrees of freedom	Mean square	F	Remarks*
Varieties	361.0443	11	32.8222	32.38	significant
Error	109.4713	108	1.0136		
Total	470.5156	119			

* At the 5% significance level.

The relative gross viscosities of the 12 varieties are not equal because the F value is significant at the 5% significance level. Therefore, Tukey's method is employed to group the viscosity means from different varieties. The least significant difference of 12 varieties is 0.8916.

$$L.S.D. = t_{0.05}(\frac{2s^2}{N}) = 1.98(\frac{2 \times 1.0136}{10}) = 0.8916$$

Therefore, on the basis of relative gross viscosity, the juice is divided into two groups, Sioux and the rest. By further test of extreme mean of the eleven varieties using the formula
$u = (\bar{x} - \bar{\bar{x}})/(s^2/N)^{\frac{1}{2}}$, the values for the relative gross viscosity are grouped into four groups as shown in Table 6. The consistency of the twelve varieties were scored 13 or more points by the P.M.A. inspector, and all were classified as grade A consistency. However, the P.M.A. grading failed to show a good relationship to the relative gross viscosity as may be seen from Table 6. The highest P.M.A. scores were given to varieties possessing the highest and lowest relative gross viscosities. It may be suspected that high serum viscosity is a factor causing a better P.M.A. consistency grading because Sioux and T-35 with the highest serum viscosities were given a score of 14. Nevertheless, this is not true with certain varieties such as O.S.C. 54, which has a higher serum viscosity than all other varieties with the exception of Sioux and T-35, and was given only 13 points for consistency. Varieties O.S.C. 31 and T-5, which were given a P.M.A. score of 14 and 14.5 showed a very low relative serum viscosity.

TABLE 6

COMPARISON BETWEEN VISCOSITIES
AND P.M.A. GRADES*

Variety	Relative gross viscosity	Relative serum viscosity (without salt)	P.M.A. grading
Sioux	8.9981	2.0502	14
T-35	6.1629	1.9368	14
T-17	5.3115	1.4729	13
Assoc. 1278	5.1615	1.3679	13
O.S.C. 54	5.0851	1.8306	13
Assoc. 1005	4.5384	1.6537	13
Queen	4.5153	1.3514	13
Assoc. 1045	4.1996	1.4997	13
O.S.C. 49	3.6681	1.6872	13
O.S.C. 31	2.9527	1.2598	14
T-5	2.5603	1.2767	14.5
Assoc. 1044	2.2864	1.2446	13

* Varieties are grouped into 4 groups according to their relative gross viscosity means by Tukey's method.

From all the data obtained, it was thought that a relationship might exist between different viscosities and other physical properties; the data were therefore subjected to statistical analysis.

5. Relationship between relative gross viscosity and rate of filtration.

From the statistical analysis in Tables 3 and 4, it was concluded that salting did not affect the rate of filtration and the relative gross viscosity. All data of relative gross viscosity and rate of filtration obtained from salted juice were therefore used with data obtained from plain juice. There are 12 varieties, each with 10 pairs of observations, totaling 120 pairs. In order to find any relationship between relative gross viscosity and rate of filtration, the estimate line of regression was used. The first step of analysis was to find out whether or not there is a relationship between these two above mentioned factors within a variety. The hypothesis of the test is that all arrays within a variety are equal, that is, the population regression coefficient is zero. The F-test was employed to test each of the 12 varieties. All F values thus obtained were not significant at the 5% significance level. The second step of the analysis is to find out whether or not there are relationships among the 12 varieties. The means of the resulting relative gross viscosities and rates of filtration from the 12 varieties were used for the calculation as shown in Table 7. The values of regression coefficients, a and b, were calculated. The values of estimated standard error of estimate, the estimated line of regression and correlation coefficient are shown in Figure 1. The relative serum viscosity value at 25°C (average of first 5 samples in each variety) is indicated after the variety name in parenthesis. The coefficient, b = 0.3197, represents the slope of the line of regression and measures the rate of change of relative gross viscosity with respect to the rate of filtration. The linear relationship is confirmed by the calculation of correlation coefficient, r, which is equal to -0.7838 with 10 degrees of freedom and is significant at the 5% significance level. The rate of filtration can thus be used as an estimate of the gross viscosity of the tomato juice. However as indicated in Figure 1, there are some varieties that deviate more than others from the line of regression; such varieties are Sioux, O.S.C. 49 and Assoc. 1278. It is expected that O.S.C. 49 with a relative gross viscosity of 3.6681 should have a rate of filtration of about 21 ml. instead of the slow rate of 14 ml. Also Assoc. 1278 which has a relative gross viscosity almost the same as O.S.C. 54 or T-17 should have a rate of filtration close to 17 ml. instead of 20.6 ml. For this reason, it is believed that there are some other factors which affect the rate of filtration. It should be noted that the three varieties, T-5, Assoc. 1044 and O.S.C. 31, with the fastest rate of filtration have a low relative gross viscosity and also a low relative serum viscosity. Since O.S.C. 49 has a higher relative serum viscosity than T-5, Assoc. 1044, O.S.C. 31, Assoc. 1005, Queen, T-17, Assoc. 1278 and Assoc. 1045, the rate of filtration is consequently slower than expected. The same explanation can be applied to Assoc. 1278. As shown in

Figure 1, the varieties, Assoc. 1278, T-17 and O.S.C. 54 all with a relative gross viscosity close to 5 have different relative serum viscosities. Their rate of filtration decreases with respect to an increasing value of the relative serum viscosity. O.S.C. 54 with a high relative serum viscosity of 1.8576 has a slower rate of filtration than T-17 and Assoc. 1278. Although the Sioux variety has the highest values of 2.0502 and 8.9981 for relative serum and gross viscosities respectively, the rate of filtration does not follow the estimated line of regression. This can be explained by the fact that the estimated line of regression is only adoptable to a certain limited extent. For example, the amount of centrifuged solids present in 100 ml. of tomato juice when mixed with sufficient distilled water to produce 100 ml. of reconstituted tomato juice gives a filtration rate of 52 ml. If this value of 52 ml. is substituted into the formula for the estimated line of regression, a negative value of relative gross viscosity, which is impossible, results. As in this experiment, the slowest rate of filtration of tomato juice was not less than 12 ml. This information is confirmed by the commercial sample LBY from Appendix Table 5. Sample LBY_1 has a rate of filtration of 12 ml. though it has a very high relative serum viscosity (the highest in these experiments) of 2.977 and a relative gross viscosity of 2.6125.

TABLE 7

AVERAGE OF RATE OF FILTRATION AND
RELATIVE GROSS VISCOSITY

Variety	Average rate of filtration ml./100 ml./15 min.	Average relative gross viscosity at 25°C
Assoc. 1045	21.725	4.1996
Assoc. 1005	17.05	4.5384
Assoc. 1278	20.60	5.1615
Sioux	12.10	8.9981
O. S. C. 31	22.75	2.9527
T-17	18.05	5.3315
O. S. C. 54	14.90	5.0851
T-35	12.675	6.1629
T-5	24.625	2.5603
Queen	17.80	4.5153
O. S. C. 49	14.125	3.6681
Assoc. 1044	24.725	2.2864

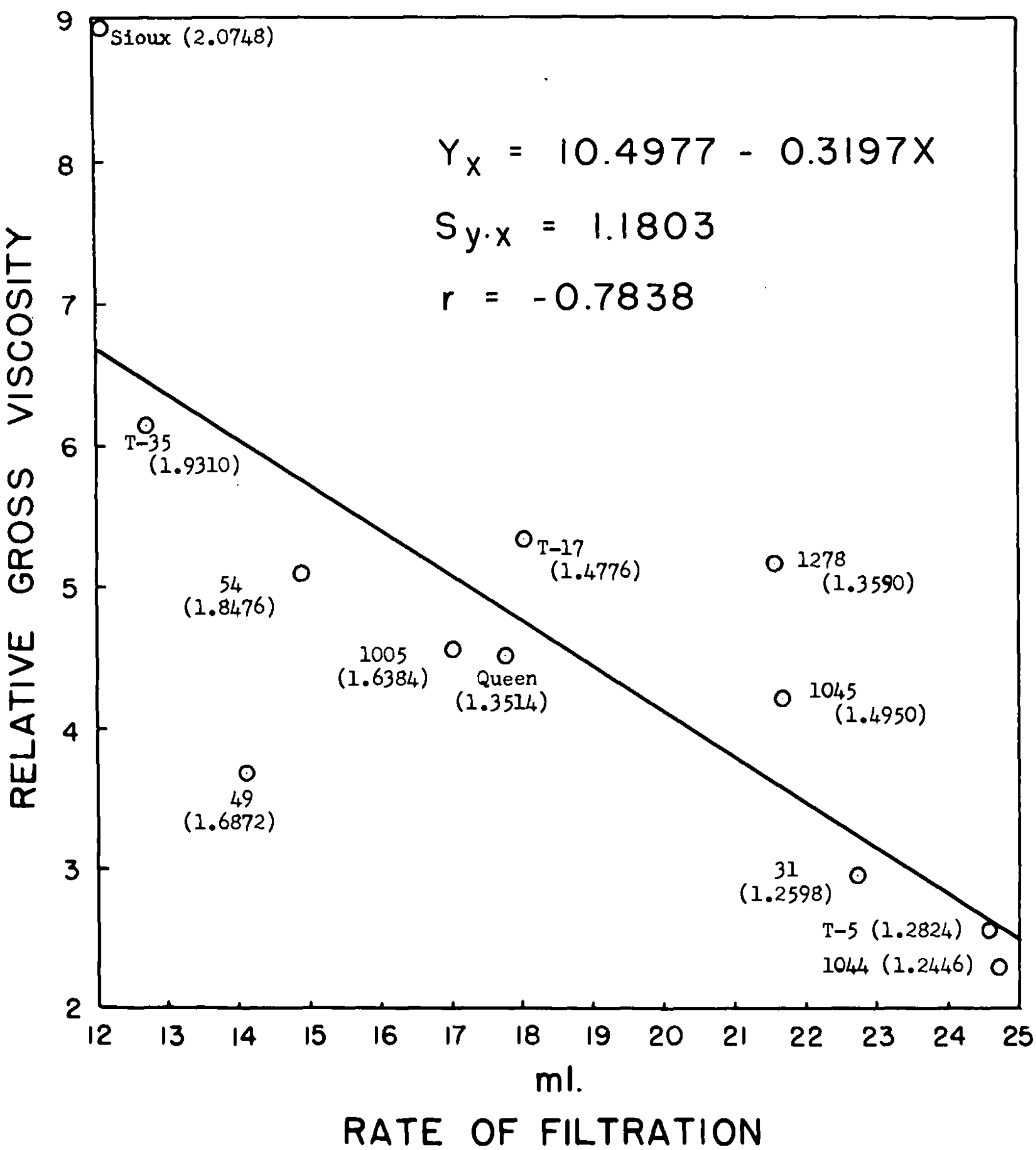

FIG. I GROSS VISCOSITY VS. RATE OF FILTRATION

6. Relationship between relative serum viscosity and rate of filtration.

From the above discussion, it seems that the serum viscosity is a factor which affects the rate of filtration. This is further to be confirmed by finding the correlation coefficient between the relative serum viscosity and the rate of filtration. Since salting has an effect on serum viscosity, only the values of the data obtained from samples number 1 to 5 of each variety were used in this statistical analysis. The correlation coefficients obtained within each variety were not significant. The average values from each variety were used to calculate the correlation coefficient among the 12 varieties. The values of regression coefficients, the estimated standard error of estimate, the estimated line of regression and the correlation coefficient are shown in Figure 2. The average volume of centrifuged solids for each variety is indicated after the variety name in parenthesis. A correlation coefficient, r, which is equal to -0.8694 with 10 degrees of freedom is significant at the 5% significance level. This correlation coefficient is comparably higher than the one obtained from the relationship between the relative gross viscosity and the rate of filtration. This information not only reveals that the relative serum viscosity has a better relationship than the gross viscosity to the rate of filtration but assures us that the rate of filtration can be used as a simple method of controlling the tomato juice serum viscosity. If this method were used to estimate the serum viscosity for quality control work, a standard curve for each variety for

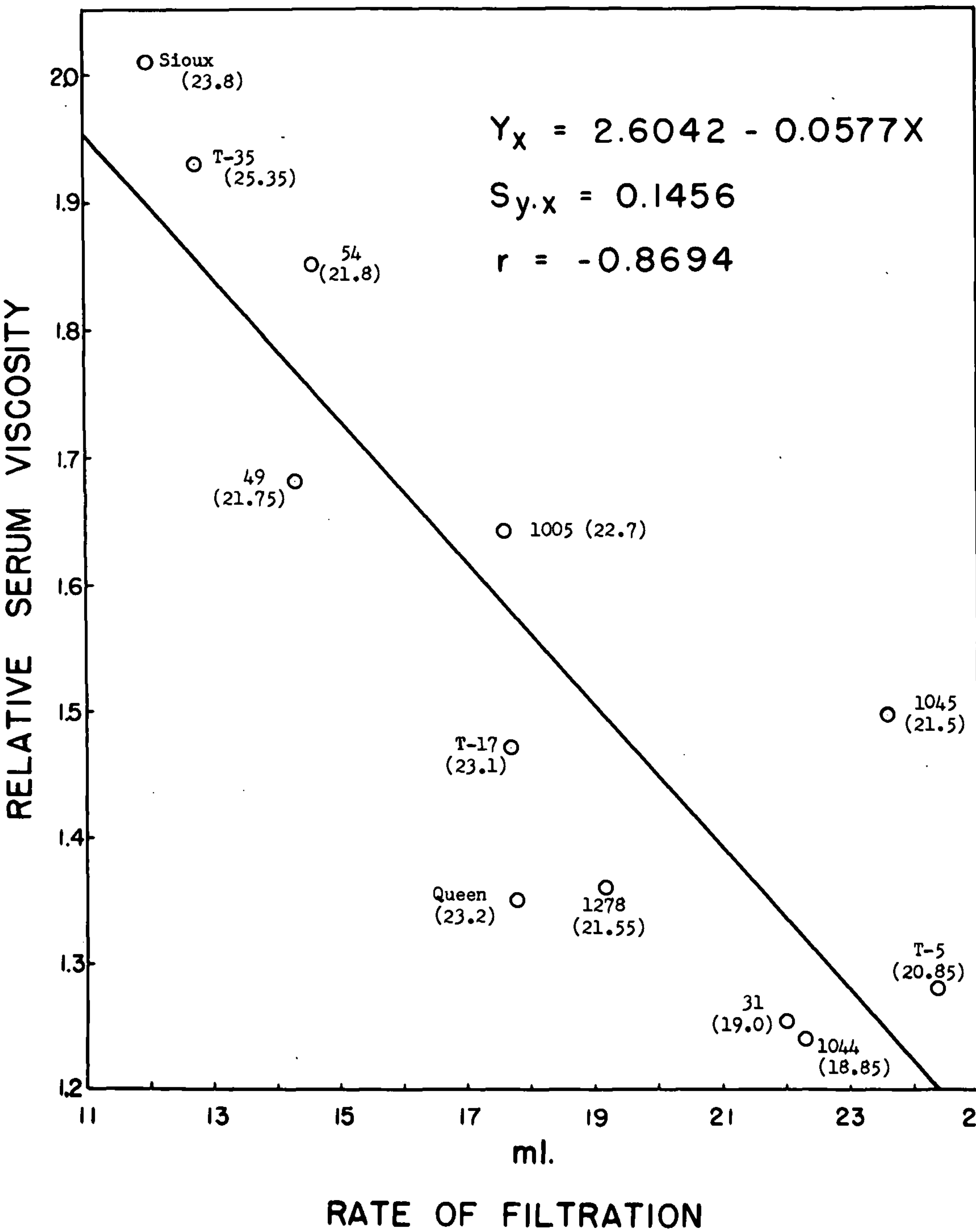

FIG. 2 SERUM VISCOSITY VS. RATE OF FILTRATION

a standard processing method would be determined as the centrifuged solids may differ among varieties. The effect of the volume of centrifuged solids upon the rate of filtration will be discussed later.

7. Relationship between relative gross viscosity and volume of centrifuged solids.

The correlation coefficient, r, between the relative gross viscosity and volume of centrifuged solids was calculated within each variety. As salting had no effect on both of these factors investigated, the data obtained from salted juice were also used. The results are shown in Table 8. Four varieties which have a significant r value with 10 degrees of freedom are indicated by an asterisk.

TABLE 8

CORRELATION COEFFICIENT BETWEEN RELATIVE GROSS VISCOSITY AND VOLUME OF CENTRIFUGED SOLIDS WITHIN EACH VARIETY

Variety	r	Variety	r
Assoc. 1045	0.7794*	O.S.C. 54	0.5265
Assoc. 1005	-0.3936	T-35	0.4711
Assoc. 1278	0.9010*	Queen	0.3027
Sioux	0.6119	O.S.C. 49	0.5846
O.S.C. 31	0.7838*	T-5	0.1003
T-17	0.0114	Assoc. 1044	0.7684*

* Significant at the 5% significance level.

The average values (including those data obtained from salted juice) of the relative gross viscosity and volume of centrifuged solids of the 12 varieties were used for calculating their correlation coefficient among all varieties, totaling 12 pairs of observations. The r value thus obtained is 0.7646 with 10 degrees of freedom which is significant at the 5% significance level. The values of estimated standard error of estimate, estimated line of regression and the correlation coefficient are shown in Figure 3. The interpretation of the results is that gross viscosity has a positive slope relation with respect to the volume of centrifuged solids. In other words, the gross viscosity increased with increasing volume of the centrifuged solids. In Figure 3, comparing the relative serum viscosity as indicated after the variety name in parenthesis from those varieties (such as O. S. C. 31 and Assoc. 1044, T-17 and Queen) having the same volume of centrifuged solids, it was found that the gross viscosity increases with an increase in serum viscosity.

8. Relationship between serum viscosity and gross viscosity.

To study the relationship between gross and serum viscosities of plain tomato juice, the correlation coefficient within each variety was calculated; and all 12 r values obtained were not significant at the 5% significance level. The average values of the relative serum and gross viscosities from samples number 1 to 5 of each variety were used to calculate the correlation coefficient among 12 varieties. A high correlation coefficient of 0.8439 with 10 degrees of freedom was obtained. The regression coefficients, the estimated standard error

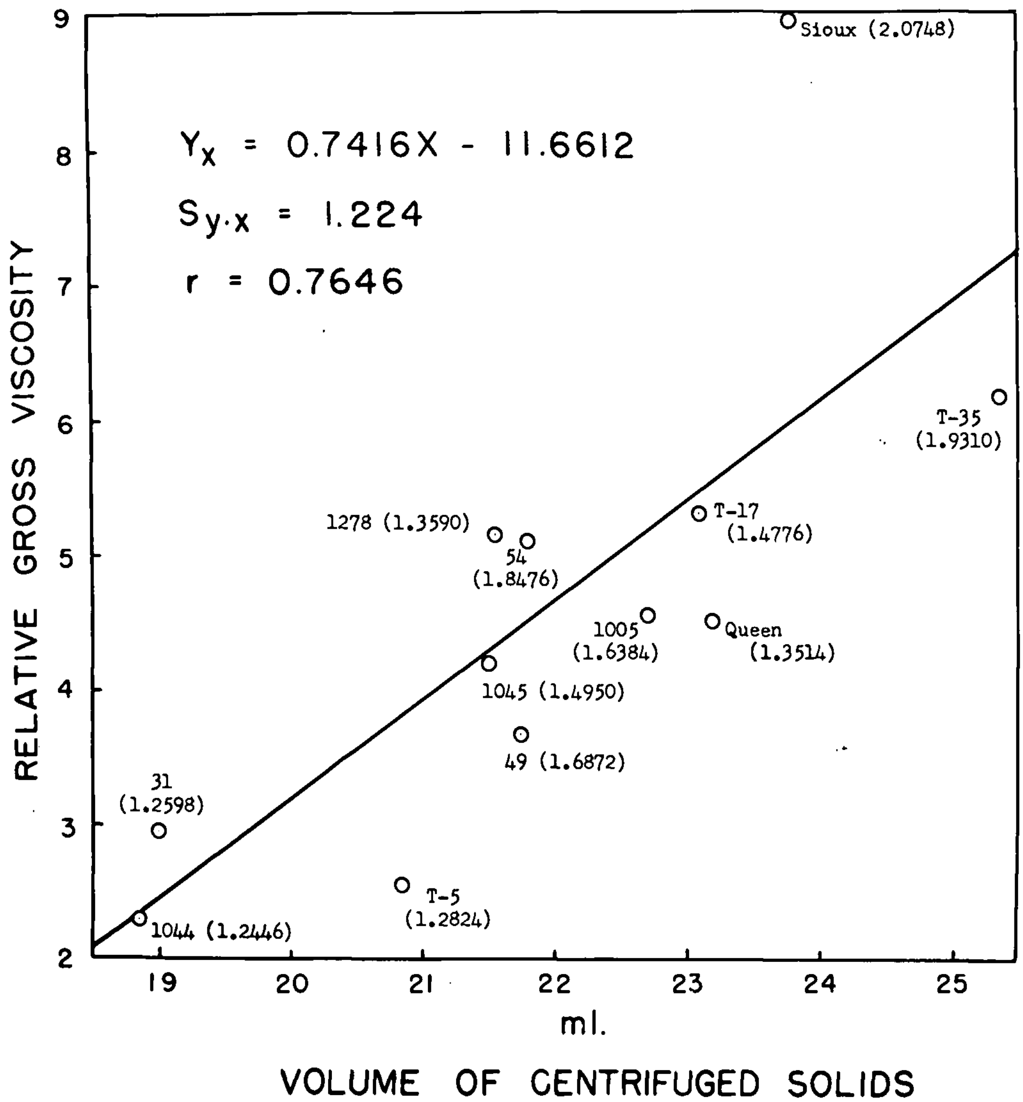

FIG. 3 GROSS VISCOSITY VS. VOLUME OF CENTRIFUGED SOLIDS

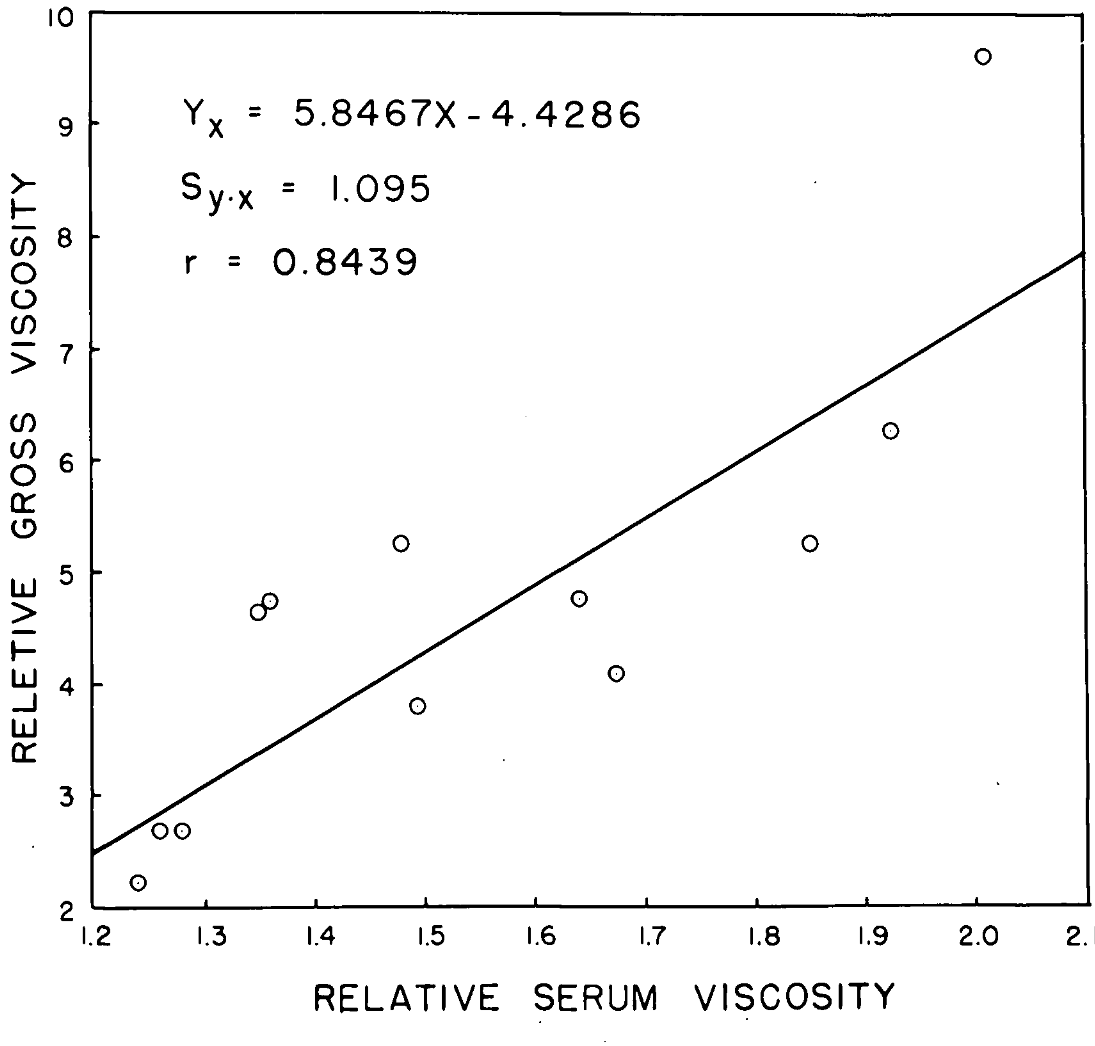

FIG. 4 GROSS VISCOSITY VS. SERUM VISCOSITY

of estimate and the estimated line of regression are shown in Figure 4. Since b is equal to 5.8467, the relative gross viscosity increases six times as fast as the relative serum viscosity. When correlation coefficients obtained from serum viscosity and from volume of centrifuged solids with respect to the gross viscosity were compared, serum viscosity had a higher correlation coefficient. Therefore, serum viscosity is considered a more important factor contributing to gross viscosity as well as to the consistency of tomato juice than suspended solids.

9. Relationship between centrifuged solids and rate of filtration.

From the previous discussion it was noted that rate of filtration was closely related to both serum viscosity and gross viscosity, and the latter was closely related to the volume of centrifuged solids. Therefore, it was advisable to study also the relationship between the volume of centrifuged solids and the rate of filtration or how the volume of the centrifuged solids affects the rate of filtration. Their correlation coefficient was calculated from the average values obtained from plain and salted juice. The r value is -0.8042 with 10 degrees of freedom and is significant at the 5% significance level. The estimated standard error of estimate, the regression coefficients and the estimated line of regression are shown in Figure 5. The regression coefficient, b, which is -1.9118 represents a negative slope of the line indicating a slow rate of filtration resulted from an increased volume of centrifuged solids. Comparing those varieties

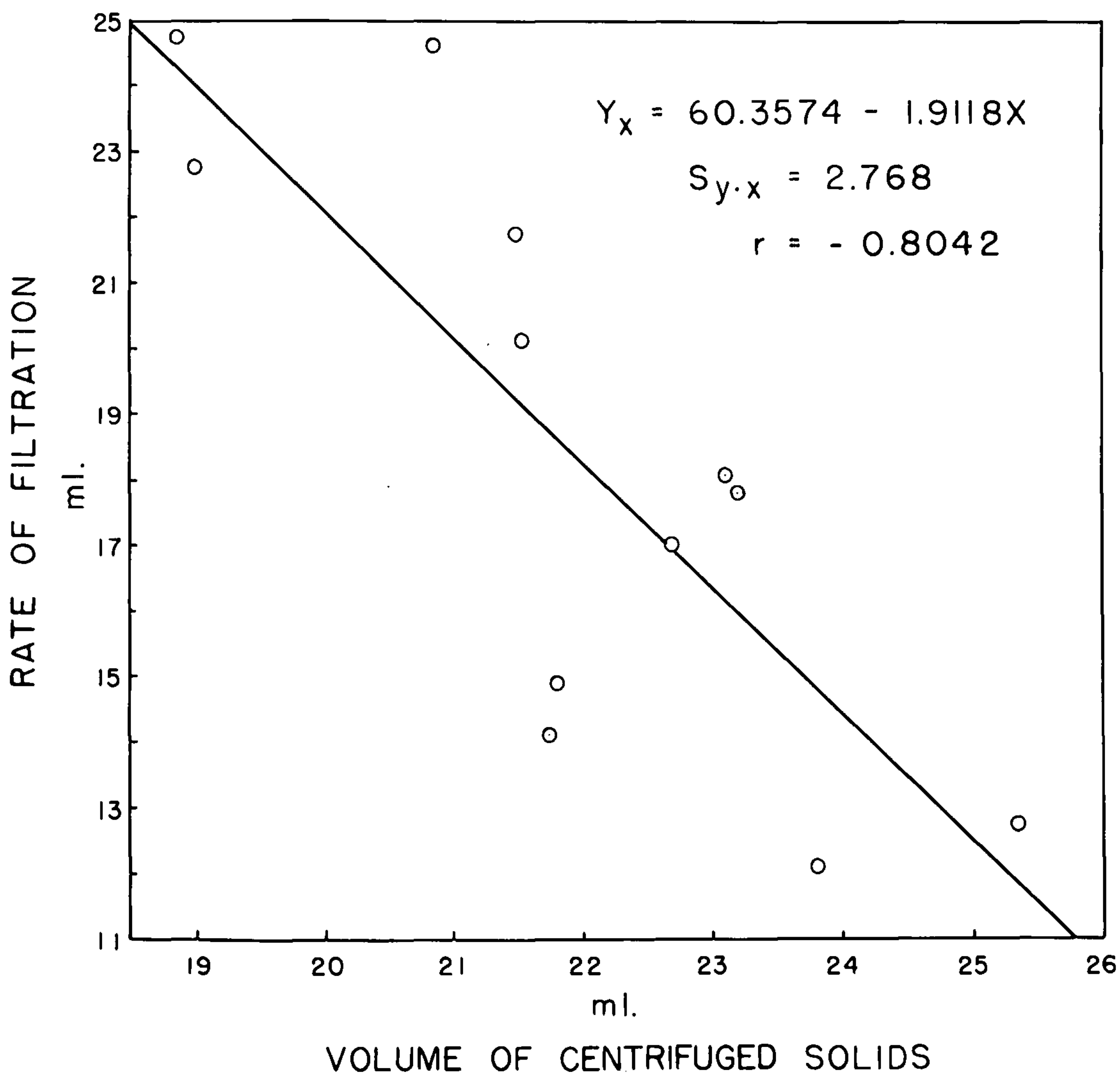

FIG. 5 RATE OF FILTRATION VS. VOLUME OF CENTRIFUGED SOLIDS

with close serum viscosity values (such as Queen and Assoc. 1278, T-17 and Assoc. 1045, O.S.C. 31 and Assoc. 1044) as indicated after the variety name in parenthesis in Figure 2, it was confirmed that their rate of filtration is affected in such a way that the smaller volume of centrifuged solids the faster the rate of filtration.

10. Relation of viscosity and other physical properties.

The effect of pH value and soluble solids upon the gross and serum viscosities was studied. All calculations were performed as mentioned previously and results are tabulated in Table 9. For calculations dealing with the serum viscosity and soluble solids, the average values obtained from plain samples number 1 to 5 were used because the salted samples affected these two factors.

TABLE 9

CORRELATION OF VISCOSITY AND OTHER TESTS

Coefficient of correlation involving	Correlation coefficient r
1. Relative gross viscosity vs. pH	0.3941
2. Relative gross viscosity vs. soluble solids	0.0868
3. Relative serum viscosity vs. pH	0.0775
4. Relative serum viscosity vs. soluble solids	0.0548

Since the r values are far from 1.0, there are hardly any correlations between these sets of values. For this reason, the variation of pH value in tomato juice neither affects gross viscosity nor serum viscosity; and the soluble solids could not be used as an index to judge the consistency of tomato juice.

11. Comparison of consistency of commercial samples and experimental samples.

The commercial samples have a smaller volume of centrifuged solids and a lower relative gross viscosity as compared to the experimental samples. The volume of centrifuged solids in commercial tomato juice stayed in the neighborhood of 16 ml. which is about 26% less as compared to experimental tomato juice based on the latter average value of 21.54 ml. The average relative gross and serum viscosities obtained from commercial (salted) and experimental (plain) tomato juice (samples numbered 1 to 5) are tabulated in Table 10.

The relative serum viscosity obtained from commercial samples ranged from about 1.2 to 1.7 with only one exception. This one exception is sample LBY, which had a very high relative serum viscosity range of 2.330 to 2.977; this value is about 100% higher than other commercial samples and about 50% higher than the highest experimental samples. Juice canned from Sioux, O.S.C. 54 and T-35 varieties of tomatoes had relative serum viscosities above 1.8 and their consistency is considered more desirable.

TABLE 10

VISCOSITIES OF COMMERCIAL AND EXPERIMENTAL TOMATO JUICE

Sample	Relative serum viscosity		Relative gross viscosity	
	mean	range	mean	range
Commercial	1.51	1.22 - 2.98	1.73	1.39 - 2.61
Experimental	1.55	1.24 - 2.08	4.66	2.25 - 9.55

V. SUMMARY AND CONCLUSION

Twelve new varieties of tomatoes grown in Oregon were processed as plain and salted tomato juice by the hot break method. They were analyzed for relative gross viscosity, relative serum viscosity, rate of filtration, soluble solids, volume of centrifuged solids and pH of the juice. Tomato juice canned from each of these varieties was graded for P.M.A. score of consistency. Nine brands of commercial canned tomato juice were analyzed for the same factors.

Analysis of variance was applied to the data and revealed that salting had no effect on gross viscosity and rate of filtration but increased the serum viscosity slightly.

Tukey's method was employed to group the relative gross viscosities from different varieties. The least significant difference of twelve varieties is 0.8916. Sioux and T-35 were the varieties belonging to the two higher gross viscosity groups. Varieties with low relative gross viscosity values were O.S.C. 49, O.S.C. 31, T-5 and Assoc. 1044.

Tomato juice canned from twelve varieties were all graded as grade "A" consistency by the Production and Marketing Administration. P.M.A. consistency scores obtained from twelve varieties do not show any correlation to the relative gross viscosity or the relative serum viscosity.

Variation of pH values and soluble solids of tomato juice do not show any correlation to the serum and gross viscosities.

Rate of filtration is correlated with serum viscosity as well as gross viscosity. Rate of filtration can be used as a simple method to measure the serum viscosity.

The volume of centrifuged solids is correlated with gross viscosity and rate of filtration.

High correlation coefficient of relative serum viscosity and relative gross viscosity revealed that the serum viscosity is a more important factor contributing gross viscosity as well as consistency of tomato juice.

The relative gross viscosity obtained from experimental samples were ranged from 2.25 to 9.95 at 25°C and their values were higher than those obtained from commercial samples which ranged from 1.39 to 2.61 at 25°C.

The relative serum viscosity obtained from experimental and commercial samples were about the same. Relative serum viscosity of unsalted experimental samples ranged from 1.24 to 2.08 at 25°C and salted commercial samples ranged from 1.22 to 2.98 at 25°C.

The average volume of centrifuged solids obtained from commercial samples was 16 ml. and was 26% lower than the volume obtained from experimental samples.

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APPENDIX

APPENDIX TABLE 1

TOMATO JUICE: RELATIVE GROSS VISCOSITY AND RATE OF FILTRATION

Varieties	Sample No.	Stormer reading in seconds	Relative gross viscosity at 25°C	Rate of filtration ml. per 100 ml. juice per fifteen minutes
Assoc. 1045	1	26.0	3.250	20.5
	2	25.95	3.244	23.0
	3	43.1	5.388	23.0
	4	37.7	4.713	25.5
	5	20.3	2.538	26.0
	6	25.2	3.150	16.75
	7	29.9	7.738	26.5
	8	51.0	6.375	15.0
	9	40.8	5.100	16.0
	10	36.0	4.500	25.0
Assoc. 1005	1	40.45	5.050	17.0
	2	45.0	5.626	16.5
	3	37.1	4.638	19.0
	4	34.3	4.288	18.5
	5	33.6	4.200	17.0
	6	34.3	4.288	17.0
	7	34.3	4.288	17.0
	8	36.1	4.513	16.5
	9	31.5	3.938	13.5
	10	36.4	4.550	18.5
Sioux	1	59.0	7.735	12.0
	2	68.2	8.525	11.0
	3	78.4	9.800	12.0
	4	80.1	10.013	13.0
	5	96.1	12.013	12.0
	6	79.2	9.900	11.0
	7	60.3	7.538	11.5
	8	42.5	5.313	12.5
	9	91.5	11.438	13.0
	10	64.5	8.066	13.0

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APPENDIX TABLE 1 (continued)

TOMATO JUICE: RELATIVE GROSS VISCOSITY AND RATE OF FILTRATION

Varieties	Sample No.	Stormer reading in seconds	Relative gross viscosity at 25°C	Rate of filtration ml. per 100 ml. juice per fifteen minutes
Assoc. 1278	1	45.8	5.725	15.5
	2	34.9	4.363	21.5
	3	33.7	4.213	18.0
	4	35.1	4.388	21.5
	5	40.4	5.050	19.5
	6	51.7	6.463	22.0
	7	46.0	5.750	20.0
	8	46.8	5.850	21.5
	9	33.7	4.213	21.5
	10	44.8	5.600	20.0
T-17	1	44.2	5.525	17.5
	2	29.8	3.725	17.75
	3	46.0	5.750	18.0
	4	49.4	6.175	17.75
	5	41.1	5.138	17.5
	6	54.1	6.763	18.75
	7	38.5	4.813	17.5
	8	37.2	4.650	18.0
	9	49.7	6.213	18.00
	10	34.9	4.363	19.75
O.S.C. 54	1	35.1	4.388	14.0
	2	49.2	6.150	14.0
	3	48.4	6.050	14.5
	4	37.4	4.675	15.0
	5	38.6	4.825	15.5
	6	23.8	2.975	15.0
	7	46.4	5.800	15.0
	8	36.2	4.525	15.0
	9	42.3	5.288	15.5
	10	49.4	6.175	15.0

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APPENDIX TABLE 1 (continued)

TOMATO JUICE: RELATIVE GROSS VISCOSITY AND RATE OF FILTRATION

Varieties	Sample No.	Stormer reading in seconds	Relative gross viscosity at 25°C	Rate of filtration ml. per 100 ml. juice per fifteen minutes
T-35	1	48.7	6.088	12.5
	2	52.7	6.588	12.75
	3	55.5	6.938	12.0
	4	48.7	6.088	13.75
	5	42.9	5.363	12.75
	6	35.6	4.450	12.0
	7	38.3	4.788	12.0
	8	59.8	7.475	13.0
	9	54.3	6.788	13.0
	10	56.5	7.063	13.0
T-5	1	24.3	3.038	22.25
	2	23.0	2.875	28.0
	3	20.5	2.563	20.75
	4	20.3	2.538	25.0
	5	18.1	2.263	26.0
	6	19.4	2.425	23.0
	7	23.3	2.913	24.0
	8	18.2	2.275	27.25
	9	17.6	2.200	26.0
	10	20.1	2.513	24.0
O.S.C. 31 (plain)	1	20.8	2.600	23.0
	2	20.7	2.588	23.25
	3	19.5	2.438	23.75
	4	22.1	2.763	24.25
	5	24.8	3.100	23.0
O.S.C. 31 (salted)	6	28.5	3.563	22.25
	7	28.0	3.500	22.25
	8	20.6	2.575	21.25
	9	24.4	3.050	21.75
	10	26.8	3.350	22.75

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APPENDIX TABLE 1 (continued)

TOMATO JUICE: RELATIVE GROSS VISCOSITY AND RATE OF FILTRATION

Varieties	Sample No.	Stormer reading in seconds	Relative gross viscosity at 25°C	Rate of filtration ml. per 100 ml. juice per fifteen minutes
Queen (plain)	1	28.7	3.588	17.25
	2	30.5	3.813	18.0
	3	38.2	4.775	18.5
	4	41.9	5.238	17.75
	5	46.6	5.825	17.5
Queen (salted)	6	28.2	3.525	17.5
	7	36.7	4.588	17.5
	8	39.5	4.938	18.5
	9	36.7	4.588	17.5
	10	34.2	4.275	18.0
O.S.C. 49 (plain)	1	27.8	3.475	13.75
	2	41.3	5.163	14.75
	3	31.8	3.975	14.0
	4	33.4	4.175	15.0
	5	28.4	3.550	14.0
O.S.C. 49 (salted)	6	32.3	4.004	13.0
	7	14.1	1.763	15.0
	8	16.9	2.113	14.0
	9	25.2	3.150	14.0
	10	42.5	5.313	13.75
Assoc. 1044 (plain)	1	15.2	1.900	22.0
	2	13.9	1.738	22.75
	3	18.3	2.288	22.0
	4	23.6	2.950	22.75
	5	18.9	2.363	22.0
Assoc. 1044 (salted)	6	27.4	3.425	25.25
	7	16.4	2.050	25.5
	8	14.4	1.800	27.0
	9	17.0	2.125	30.0
	10	17.8	2.225	28.0

APPENDIX TABLE 2

MEASUREMENT OF RELATIVE VISCOSITY OF THE TOMATO JUICE SERUM

Varieties	Sample No.	t_1 Ostwald reading in seconds	d_1/d_2 density ratio	Relative serum viscosity at 25°C
Assoc. 1045	1	151.4	1.0289	1.483
	2	155.8	1.0277	1.524
	3	155.2	1.0273	1.518
	4	156.8	1.0277	1.436
	5	154.8	1.0277	1.514
	6	153.7	1.0281	1.504
	7	156.1	1.0273	1.527
	8	153.4	1.0277	1.501
	9	152.2	1.0277	1.489
	10	153.5	1.0273	1.501
Assoc. 1005	1	165.65	1.0237	1.614
	2	167.5	1.0237	1.632
	3	167.45	1.0237	1.632
	4	166.1	1.0233	1.618
	5	174.0	1.0237	1.696
	6	178.2	1.0245	1.738
	7	174.85	1.0237	1.704
	8	169.95	1.0233	1.655
	9	167.8	1.0233	1.635
	10	165.55	1.0237	1.613
Sioux	1	214.55	1.0275	2.095
	2	211.0	1.0269	2.063
	3	212.0	1.0261	2.071
	4	211.3	1.0257	2.063
	5	213.2	1.0261	2.082
	6	208.8	1.0257	2.039
	7	212.3	1.0261	1.976
	8	207.5	1.0257	2.026
	9	208.3	1.0257	2.034
	10	210.3	1.0257	2.053

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APPENDIX TABLE 2 (continued)

MEASUREMENT OF RELATIVE VISCOSITY OF THE TOMATO JUICE SERUM

Varieties	Sample No.	t_1 Ostwald reading in seconds	d_1/d_2 density ratio	Relative serum viscosity at 25°C
Assoc. 1278	1	138.4	1.0289	1.355
	2	141.4	1.0289	1.388
	3	137.4	1.0289	1.346
	4	138.0	1.0289	1.352
	5	138.3	1.0285	1.354
	6	140.5	1.0285	1.376
	7	140.5	1.0293	1.377
	8	142.7	1.0285	1.397
	9	139.8	1.0285	1.369
	10	139.4	1.0285	1.365
T-17	1	149.1	1.0253	1.455
	2	152.1	1.0257	1.485
	3	151.3	1.0249	1.476
	4	152.6	1.0249	1.489
	5	151.9	1.0253	1.483
	6	149.0	1.0253	1.454
	7	149.3	1.0249	1.457
	8	152.3	1.0257	1.487
	9	151.9	1.0253	1.483
	10	149.4	1.0249	1.458
O.S.C. 54	1	190.0	1.0237	1.852
	2	190.0	1.0229	1.850
	3	186.6	1.0241	1.819
	4	190.0	1.0233	1.851
	5	191.7	1.0225	1.866
	6	185.4	1.0225	1.805
	7	185.2	1.0225	1.803
	8	185.0	1.0223	1.802
	9	187.1	1.0229	1.822
	10	188.7	1.0233	1.836

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APPENDIX TABLE 2 (continued)

MEASUREMENT OF RELATIVE VISCOSITY OF THE TOMATO JUICE SERUM

Varieties	Sample No.	t_1 Ostwald reading in seconds	d_1/d_2 density ratio	Relative serum viscosity at 25°C
T-35	1	194.6	1.0245	1.898
	2	196.4	1.0245	1.915
	3	198.2	1.0241	1.932
	4	201.0	1.0241	1.959
	5	200.1	1.0241	1.951
	6	196.6	1.0241	1.917
	7	199.8	1.0241	1.948
	8	201.5	1.0241	1.964
	9	198.0	1.0241	1.930
	10	200.2	1.0241	1.954
T-5	1	136.8	1.0221	1.331
	2	134.4	1.0225	1.308
	3	128.8	1.0221	1.253
	4	131.3	1.0221	1.278
	5	127.6	1.0221	1.242
	6	130.9	1.0221	1.274
	7	138.5	1.0221	1.348
	8	124.4	1.0217	1.210
	9	127.9	1.0229	1.245
	10	131.3	1.0221	1.278
O.S.C. 31 (plain)	1	129.2	1.0289	1.265
	2	128.7	1.0285	1.260
	3	128.2	1.0285	1.255
	4	127.5	1.0298	1.250
	5	129.6	1.0293	1.269
O.S.C. 31 (salted)	6	127.3	1.0334	1.252
	7	128.4	1.0334	1.263
	8	129.8	1.0330	1.276
	9	129.8	1.0330	1.276
	10	129.3	1.0322	1.270

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APPENDIX TABLE 2 (continued)

MEASUREMENT OF RELATIVE VISCOSITY OF THE TOMATO JUICE SERUM

Varieties	Sample No.	t_1 Ostwald reading in seconds	d_1/d_2 density ratio	Relative serum viscosity at 25°C
Queen (plain)	1	136.6	1.0310	1.341
	2	136.4	1.0310	1.339
	3	136.2	1.0310	1.337
	4	139.6	1.0310	1.371
	5	139.4	1.0318	1.369
Queen (salted)	6	139.9	1.0346	1.378
	7	138.9	1.0342	1.367
	8	139.7	1.0342	1.375
	9	141.7	1.0338	1.394
	10	138.7	1.0338	1.365
O.S.C. 49 (plain)	1	172.2	1.0289	1.692
	2	175.0	1.0289	1.714
	3	172.6	1.0293	1.692
	4	171.3	1.0289	1.678
	5	169.5	1.0289	1.660
O.S.C. 49 (salted)	6	175.7	1.0326	1.727
	7	174.2	1.0330	1.713
	8	176.4	1.0322	1.733
	9	177.3	1.0322	1.742
	10	176.8	1.0322	1.737
Assoc. 1044 (plain)	1	128.5	1.0241	1.253
	2	126.3	1.0233	1.230
	3	128.6	1.0249	1.254
	4	127.3	1.0249	1.242
	5	127.5	1.0249	1.244
Assoc. 1044 (salted)	6	130.5	1.0281	1.277
	7	128.1	1.0281	1.254
	8	131.0	1.0281	1.282
	9	134.4	1.0281	1.315
	10	130.1	1.0281	1.273

APPENDIX TABLE 3

DATA OF CENTRIFUGED SOLIDS, SOLUBLE SOLIDS AND pH VALUE

Varieties	Sample No.	Volume of centrifuged solids ml./100 ml. juice	Total soluble solids (refracto. mthd.)	pH
Assoc. 1045	1	21.0	5.2	4.3
	2	22.0	5.5	4.35
	3	22.5	5.2	4.35
	4	21.5	5.2	4.35
	5	19.5	5.2	4.4
	6	20.5	5.4	4.35
	7	21.5	5.2	4.45
	8	23.5	5.2	4.40
	9	22.0	5.2	4.40
	10	21.0	5.4	4.45
Assoc. 1005	1	23.0	5.4	4.4
	2	22.0	5.4	4.45
	3	23.0	5.6	4.55
	4	22.0	5.4	4.5
	5	23.0	5.2	4.55
	6	23.0	5.4	4.5
	7	22.0	5.6	4.6
	8	22.0	5.2	4.5
	9	24.0	5.6	4.5
	10	23.0	5.6	4.5
Sioux	1	24.5	6.0	4.4
	2	23.5	6.0	4.4
	3	23.5	5.8	4.4
	4	23.5	6.0	4.4
	5	25.5	5.6	4.4
	6	24.0	5.6	4.4
	7	22.5	5.8	4.45
	8	23.5	6.0	4.4
	9	25.0	6.0	4.4
	10	22.5	6.0	4.4

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APPENDIX TABLE 3 (continued)

DATA OF CENTRIFUGED SOLIDS, SOLUBLE SOLIDS AND pH VALUE

Varieties	Sample No.	Volume of centrifuged solids ml./100 ml. juice	Total soluble solids (refracto. mthd.)	pH
Assoc. 1278	1	22.5	5.4	4.45
	2	22.5	5.4	4.45
	3	21.0	5.4	4.45
	4	21.0	5.4	4.45
	5	21.5	5.2	4.45
	6	20.5	5.4	4.45
	7	21.5	5.5	4.5
	8	22.0	5.4	4.45
	9	21.0	5.2	4.45
	10	22.0	5.2	4.5
T-17	1	25.0	4.6	4.4
	2	22.5	4.8	4.4
	3	23.0	4.6	4.4
	4	22.0	4.8	4.4
	5	21.5	4.8	4.4
	6	22.5	4.8	4.35
	7	24.0	4.5	4.4
	8	24.0	4.6	4.4
	9	24.0	4.6	4.35
	10	22.5	4.8	4.4
O.S.C. 54	1	21.0	4.8	4.2
	2	22.0	4.6	4.2
	3	20.0	4.6	4.2
	4	22.5	4.6	4.2
	5	22.5	4.6	4.2
	6	21.0	4.7	4.2
	7	24.0	4.6	4.2
	8	21.5	4.7	4.2
	9	21.5	4.6	4.2
	10	22.0	4.6	4.2

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APPENDIX TABLE 3 (continued)

DATA OF CENTRIFUGED SOLIDS, SOLUBLE SOLIDS AND pH VALUE

Varieties	Sample No.	Volume of centrifuged solids ml./100 ml. juice	Total soluble solids (refracto. mthd.)	pH
T-35	1	25.0	5.4	4.2
	2	26.0	5.6	4.1
	3	25.0	5.6	4.15
	4	25.0	5.6	4.1
	5	24.5	5.6	4.15
	6	26.0	5.6	4.1
	7	25.0	5.6	4.15
	8	26.0	5.6	4.1
	9	25.0	5.6	4.1
	10	26.0	5.6	4.1
T-5	1	20.5	5.2	4.1
	2	20.5	5.2	4.1
	3	21.0	5.2	4.1
	4	21.0	5.2	4.15
	5	20.0	5.2	4.15
	6	20.0	5.2	4.1
	7	21.5	5.2	4.1
	8	21.0	5.1	4.1
	9	21.0	5.2	4.1
	10	22.0	5.2	4.1
O.S.C. 31 (plain)	1	18.5	5.0	4.3
	2	19.0	5.0	4.25
	3	18.5	5.0	4.3
	4	19.0	5.0	4.3
	5	19.0	5.0	4.3
O.S.C. 31 (salted)	6	20.5	5.8	4.2
	7	20.5	5.8	4.2
	8	16.5	5.8	4.25
	9	18.5	5.8	4.25
	10	20.0	5.8	4.2

(continued on next page)

APPENDIX TABLE 3 (continued)

DATA OF CENTRIFUGED SOLIDS, SOLUBLE SOLIDS AND pH VALUE

Varieties	Sample No.	Volume of centrifuged solids ml./100 ml. juice	Total soluble solids (refracto. mthd.)	pH
Queen (plain)	1	23.5	7.0	4.2
	2	22.5	7.0	4.2
	3	23.5	7.0	4.2
	4	23.5	7.0	4.2
	5	24.0	7.2	4.2
Queen (salted)	6	22.0	7.8	4.2
	7	22.5	7.8	4.15
	8	24.5	7.8	4.2
	9	22.0	7.8	4.2
	10	24.0	7.8	4.2
O.S.C. 49 (plain)	1	21.5	7.0	4.1
	2	23.0	7.0	4.1
	3	24.0	7.2	4.1
	4	23.0	7.1	4.1
	5	22.0	7.2	4.1
O.S.C. 49 (salted)	6	22.5	7.6	4.1
	7	17.0	7.6	4.1
	8	19.0	7.6	4.0
	9	22.5	7.6	3.95
	10	23.0	7.6	3.95
Assoc. 1044 (plain)	1	18.0	5.6	4.2
	2	17.0	5.7	4.2
	3	18.5	5.7	4.1
	4	20.0	5.7	4.1
	5	18.5	5.7	4.1
Assoc. 1044 (salted)	6	20.5	6.6	4.1
	7	18.0	6.6	4.05
	8	18.0	6.6	4.1
	9	20.0	6.6	4.1
	10	20.0	6.6	4.1

APPENDIX TABLE 4

P.M.A. GRADING OF COLOR, CONSISTENCY AND FLAVOR

Varieties	Color		Consistency		Flavor		Grade
	Score	Description	Score	Description	Score	Description	
T-5	25	Fairly bright	15	Good	33	Good	C
T-5	25	Fairly bright	13	Good	33	Good	C
T-17	24	Fairly bright	13	Good	33	Good	C
T-17	24	Fairly bright	13	Good	33	Good	C
T-35	20	Poor, light orange color	14	Good	24	Poor, green	D
T-35	20	Poor, orange color	14	Good	24	Poor, green	D
Queen	23	Fairly bright	13	Good	31	Fairly good	C
Queen	23	Fairly bright	13	Good	31	Fairly good	C
Sioux	23	Fairly bright	14	Good	32	Fairly good	C
Sioux	23	Fairly bright	14	Good	31	Fairly good	C
O.S.C. 31	23	Fairly bright	14	Good	25	Green	D
O.S.C. 31	20	Poor, very light orange	14	Good	25	Green	D
O.S.C. 49	20	Poor, orange green	13	Good	27	Fairly good	D
O.S.C. 49	20	Poor, green	13	Good	27	Fairly good	D
O.S.C. 54	23	Fairly bright	13	Good	24	Bitter	D
O.S.C. 54	23	Fairly good	13	Good	24	Bitter	D
Assoc. 1005	25	Fairly good	13	Good	32	Fairly good	C
Assoc. 1005	25	Fairly good	13	Good	32	Fairly good	C
Assoc. 1044	23	Fairly good	13	Good	30	Fairly good	C
Assoc. 1044	23	Fairly good	13	Good	30	Fairly good	C
Assoc. 1045	20	Poor, light	13	Good	30	Fairly good	D
Assoc. 1045	20	Poor, light	13	Good	30	Fairly good	D
Assoc. 1278	23	Fairly good	13	Good	33	Good	C
Assoc. 1278	23	Fairly good	13	Good	33	Good	C

APPENDIX TABLE 5

DATA AND RESULTS FROM COMMERCIAL SAMPLES

Sample	Stormer reading in seconds	Relative gross viscosity at 25°C	Ostwald reading in seconds	d_1/d_2 density ratio	Relative serum viscosity at 25°C	Volume of centrifuged solids ml./100 ml. juice	Rate of filtration ml. per 100 ml. juice per min.
CP	11.9	1.4875	126.3	1.0285	1.237	15.0	56.0
$D-L_1$	11.1	1.3875	132.7	1.0414	1.303	14.0	65.5
$D-L_2$	11.2	1.400	137.5	1.0306	1.349	13.0	51.0
ELS	16.6	2.0275	155.2	1.0318	1.524	15.0	36.75
H	11.6	1.4500	121.3	1.0283	1.189	17.0	48.5
LBY_1	20.9	2.6125	304.2	1.0281	2.977	19.0	12.0
LBY_2	17.7	2.2125	237.3	1.0310	2.330	20.5	12.0
LBY_3	18.7	2.3375	263.7	1.0314	2.589	20.5	15.0
$S-D_1$	11.9	1.4875	124.9	1.0273	1.221	14.0	67.0
$S-D_2$	17.0	2.1250	172.1	1.0362	1.698	18.5	12.0
STBY	12.9	1.6125	147.1	1.0285	1.440	15.5	35.0
S-W	13.6	1.7000	128.1	1.0285	1.254	16.0	57.0
P-L (no salt)	19.7	2.4625	126.2	1.0285	1.236	18.5	42.75

APPENDIX TABLE 6

PRELIMINARY CALCULATIONS OF ANALYSIS OF VARIANCE
FOR SALTING EFFECT ON GROSS VISCOSITY

Source of variation	Total of squares	Number of items squared	Observation per squared item	Total of squares per observation	Sum of squares
Correction	18016.3506	1	40	450.4087	0
Varieties	4778.8954	4	10	477.8895	27.4808
Treatment	9011.0194	2	20	450.5510	0.1423
Varieties plus Treatment	2401.6287	8	5	480.3257	29.9170
Individual observation	498.6341	40	1	498.6341	48.2154