AN INVESTIGATION INTO THE FACTORS
INFLUENCING THE CONSISTENCY OF
TOMATO CATSUP

by

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Submitted in Partial Fulfillment of the
Requirements for the
Degree of Bachelor of Science
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Signature of Faculty Supervisor

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Burton House
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16 May 1952

Professor Joseph S. Newell,
Secretary of the Faculty,
Massachusetts Institute of Technology
Cambridge, Massachusetts.

Dear Sir,

A thesis entitled "An Investigation into the Factors Influencing the Consistency of Tomato Catsup" is hereby submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Food Technology.

Respectfully submitted,

Edward S. Olney
ACKNOWLEDGEMENTS

The author wishes to acknowledge the helpful suggestions and supervision of Professor Bernard E. Proctor, thesis supervisor.

Acknowledgement and thanks are also made to Mr. Neal Beach, for pointing out the need for such an investigation.

The author is also indebted to Dr. P. E. Rollhaus of the Wallerstein Company for his helpful assistance in supplying a highly active enzyme preparation.
SUMMARY

A survey of the literature showed that the important factors influencing the consistency of tomato catsup are the following:

1. The degree of pectinic acids retention, which is favorably influenced by inactivating the pectic enzyme system in the macerate with a "hot break" temperature of 185°F., and by using a minimum of heat exposure in processing. The pectinic acids probably contribute to consistency by increasing the relative viscosity of the serum.

2. The formula of catsup, which influences consistency primarily through the quantity of tomato solids and quantity of sugar.

3. The screen sizes of cyclones, shaker screens, and finishers used in manufacture, which influence the quantity and size distribution of insoluble matter in the tomato solids.

No data is given in the literature to indicate the relative importance or quantitative effect of any given factor on consistency.

The experimental work confirmed the importance of pectinic acids content, tomato solids level, and screen sizes, in determining the consistency of catsup. Large variations of sugar in the formula were also shown to influence consistency.

For a fixed set of screen sizes and a fixed formula, the quantitative relationship was determined between consistency and pectinic acids content at different levels of tomato solids. It was shown that this data can be expressed graphically so that the tomato solids required to give a desired consistency can be predicted at any given level of pectinic acids retention.

The results show that data relating consistency with tomato solids
and pectinic acids must be obtained for a fixed set of manufacturing conditions, due to the influence of screen sizes and of formula in altering consistency.

It was suggested that a method of estimating pectinic acids retention be developed, such that the volume of acetone or alcohol precipitate in a hot-water extract be the measured value. Such a method could be rapid, and would be more likely to correlate with consistency than the method used in this report.

It was pointed out that a method is available for estimating the tomato solids in catsup under given conditions of screen sizes. Such a method would be based on the consistency obtained after digesting the pectinic acids with pectinase, compared with a standard curve. A method employing this principle should provide a better check on standardization methods in manufacture than present analytical methods.
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INTRODUCTION

The purpose of this investigation is to determine the primary factors which influence the consistency of tomato catsup, and to obtain data relating the controlling variables. It is intended that such data might serve as a basis for more rigid control of consistency in catsup manufacture.

The need for accurate control of consistency in the manufacture of catsup is evident. Both the competitive and seasonal natures of this product require that it be of highest quality, and yet rigidly economical to produce. Thumb-rule control risks violation of Food and Drug Administration requirements on one hand, and a decrease in yield on the other; the variation in quality between these extremes adversely affects consumer acceptance.

A desirable product which is uniform in flavor, color, and consistency can only be attained by careful control of the manufacturing process. This work is concerned only with the control of consistency, insofar as it can be independent of other quality factors.
LITERATURE SURVEY

The judgment of consistency by subjective means was associated with the art of judging the finishing point of a batch of catsup without the aid of the refractometer or the specific gravity cup. The "pour" of catsup, or its ability to "stand up" was attributed almost entirely to the degree of concentration.

As objective methods of determining the finishing point became widely adopted, it became more evident that several factors were involved in determining consistency, for catsups of the same total solids or specific gravity could differ markedly in consistency. As outlined by Schoenfeld (1950), these general factors are now recognized in the industry to be (1) the degree of pectin retention; (2) variations in the formula; (3) the size screens used in cyclones, shaker screens, and finishers. The published works pertinent to these factors are reviewed below.

In the discussion relating to the pectic substances, a definition of terms is required, due to the confusion in the literature. The following definitions are those adopted by the American Chemical Society in 1944:*  

"Pectic substances. Pectic substances is a group designation for those complex, colloidal carbohydrate derivatives which occur in, or are prepared from, plants and contain a large proportion of anhydro-galacturonic acid units which are thought to exist in a chain-like combination. The carboxyl groups of polygalacturonic acids may be partly esterified by methyl groups and partly or completely neutralized by one or more bases.

"Protopectin. The term protopectin is applied to the water-insoluble parent substance which occurs in plants and which, upon restricted hydrolysis, yields pectinic acids.

"Pectinic acids. The term pectinic acids is used for colloidal polygalacturonic acids containing more than a negligible proportion of methyl ester groups. Pectinic acids, under suitable conditions, are capable of forming gels (jellies) with sugar and acid or, if suitably low in methoxyl content, with certain metallic ions. The salts of pectinic acids are either normal or acid pectinates.

"Pectin. The general term pectin (or pectins) designates those water-soluble pectinic acids of varying methyl ester content and degree of neutralization which are capable of forming gels with sugar and acid under suitable conditions.

"Pectic acid. The term pectic acid is applied to pectic substances mostly composed of colloidal polygalacturonic acids and essentially free from methyl ester groups. The salts of pectic acid are either normal or acid pectinates."

Also of importance in the discussion of the pectic substances are the various enzymes which act upon them. The following enzymes are recognized by Kertesz (1951):

Pectin-polygalacturonase: The substrate of this enzyme is pectic acid, the complete hydrolysis of which results in the monomer D-galacturonic acids.

Pectin-methylesterase: This enzyme acts on pectinic acids, removing methyl ester groups to give pectic acid.

Pectinase: This term is applied to a preparation which contains more than one specific enzyme acting on pectic substances.

The role of pectinic acids in influencing catsup consistency was realized before the full significance of preheating tomato pulp was understood. The so-called "hot break" method of treating tomatoes resulted in a product which had a better consistency, and showed less separation of serum from solids. The first edition of Cruess' textbook
makes the statement: "The tomatoes are in most factories pulped cold, but it has been proved that boiling the tomatoes before pulping extracts pectin from the seed coats and skins, causing the catsup to be of thicker consistency and to respond favorably to the blotter test."*

Wildman (1930) investigated the effect of removal of skins and seed region before pulping, and concluded that the beneficial effect of hot pulping was not caused by any significant difference in the amount of pectin extracted from these parts. Instead he found that pectin was lost rapidly in a cold macerate, while not in a hot one. From this he suggested the enzymatic degradation of pectin in cold pulp. This was confirmed by Kertesz (1938).

Hinton (1940) studied the action of pectinase in heated and unheated fruit juices, and concluded that pectin was lost from unheated juice through enzymatic demethylation and subsequent precipitation as the calcium salt. McCulloch and Kertesz (1949) investigated the possibility that this situation occurred in unheated tomato pulp, and found that less than ten per cent of the losses could occur in this manner. Kertesz (1938) determined that tomatoes had high pectin-methylesterase activity, but low pectin-polygalacturonase activity. McCulloch and Kertesz (1949) surmised that the small activity of pectin-polygalacturonase in tomatoes could not cause the observed rapid loss of pectinic acids in a cold macerate, and the presence of a third specific pectic enzyme was ascertained. This

* W. V. Cruess, Commercial Fruit and Vegetable Products (New York, 1924), p. 320.
enzyme, which the authors called "depolymerase", apparently attacks the pectic acid polymer at many points in the chain, rapidly resulting in low molecular weight units which have little effect upon consistency. The cooperative action of pectin-methylesterase with depolymerase is responsible for the rapid loss of high molecular weight pectinic acids in a cold macerate.

While many in the industry use a "hot break" of 160°F. (Schoenfeld, 1950), Kertesz considers at least 180°F. to be sufficient. McCulloch, Nielsen, and Beavens (1950), investigating pectic changes in the processing of California tomato paste, showed that an increased retention of pectinic acids and a better consistency could be obtained by preheating at a higher temperature, and 185°F. was suggested.

In spite of an efficient "hot break" system which rapidly brings the macerate up to temperature, a calculation using the data of McCulloch shows that even in the best tomato pastes, only about fifty per cent retention of pectinic acids is attained. While some of this loss may result from the removal of coarse material in cyclones, shaker screens, and finishers, undoubtedly heat exposure is the principal cause of this loss. The data of Merrill and Weeks (1945) shows that there is a rapid loss of relative viscosity of pectinic acid solutions at 100°C., while the heat effect decreases rapidly below 80°C. This indicates that the processing of tomatoes to make catsup should employ a minimum of heat exposure. Efforts must especially be made to shorten holding periods, and to use low temperature evaporation if possible. These recommendations are embodied in the review of Schoenfeld (1950) on the manufacture of
high quality catsup.

While the role of pectinic acids in the consistency of tomato products is generally accepted, there is much to be explained concerning their mode of action and quantitative effects. Kertesz (1951), in a review of the literature and of his own work, states that the principal consistency factors in tomato juice are the quantity, average size, and size distribution of suspended particles, and the viscosity of the serum. Special emphasis is laid upon the colloidal nature of suspended particles in tomato juice, but in more concentrated products, such as paste, puree, and catsup, the role of the pectinic acids in the serum is believed to be more important.

Assuming that the sole contribution of pectinic acids in improving the consistency of catsup lies in the effect on the viscosity of the serum, it must still be recognized that many interrelated factors may affect this viscosity. They may be enumerated as follows:

1) The concentration of pectinic acids in the serum.
2) The molecular weight distribution of the pectinic acids.
3) The degree of esterification of the pectinic acids.
4) The pH of the serum.
5) The kind and amount of dissolved substances, including sugars, electrolytes, proteins, and other organic compounds.

None of these variables can be considered entirely independent in the catsup serum, with the possible exception of some of the added substances. Kertesz states that the relative viscosity of pectinic acid solutions containing added substances is, in general, the relative viscosity of the pectin plus the relative viscosity of the added substances. This consideration is of importance when the formula is
discussed below.

When the possible interrelationships between the above factors are considered, it is readily seen that the situation in catsup is exceedingly complicated. This becomes even more involved when it is realized that possible interaction occurs between the substances in the serum and the suspended particles. Much clarification could be attained if some factor could be obtained which rigidly relates the pectinic acids content of catsup with the consistency. At present there appears to be no work in the literature which shows a close correlation between consistency and any given fraction of the determined pectinic acids. One difficulty in obtaining such a correlation lies in the fact that it has only been attempted for different samples, as in the work of McCulloch discussed below. Unfortunately, the level of pectinic acids content of different samples is not the only significant variable, in the general case. It would be desirable to obtain data relating consistency to pectinic acids content in a single sample in which the pectinic acids level is the independent variable. The possibility of accomplishing this exists: (1) through the addition of pectin; (2) through the decrease in the natural level by heat or enzymatic degradation. Kertesz (1951) states that the beneficial effect of added pectin has been noted in catsup. The difficulty is that it would be virtually impossible to reproduce the naturally occurring pectinic acids, since infinite variations are possible in molecular weight distribution, degree of methylation, and other structural and composition factors. It might therefore be expected that the consistency factor of added pectinic acids would not be a sufficient reproduction of the naturally occurring pectinic acids.
The degradation of the naturally occurring pectinic acids in the catsup is more promising. Kertesz cites an experiment in which the change in consistency of tomato paste was determined by digestion with a commercial pectinase. The consistency change noted in such an experiment may correctly be a measure of the consistency factor of the pectinic acids if it can be assumed that the enzyme is specific for the pectinic acids, and the degradation is a reproduction of that which takes place in processing.

A work which shows considerable correlation between consistency and pectinic acids content is the previously cited paper of McCulloch, Nielsen, and Beavens. In this experiment, the authors determined three fractions of the pectinic acids (and their derivatives or precursors). These fractions were,

1. The hot-water soluble fraction, which is principally the fraction dissolved in the serum.

2. The acid-soluble fraction, which is principally that remaining unextracted in the insoluble matter.

3. The ammonium oxalate soluble fraction, which is that water-insoluble portion that has been lost from (1) and (2) through precipitation with polyvalent positive ions, especially calcium.

The authors, however, later reported only the total pectic substances, determined from the alcohol insoluble solids as calcium pectate by the method of Carre and Hanes. It was decided that this determination best represented the high molecular weight portion of the pectinic acids which probably contribute to consistency. Indeed, the data shows a definite trend between pastes of varying consistencies, and the per
cent calcium pectate, in spite of the fact that the total solids of
the tomato pastes varied between 21.9 and 24.7 per cent, and the
insoluble solids varied between 2.4 and 3.5 per cent.

Such was the lack of correlation between the solids and the
consistency of the pastes that the authors made the statement:

"Attempts are frequently made to increase the consistency of
thin pastes by increasing their solids content beyond the legally
defined minimum. This practice cannot be fruitful, as available
data indicate that solids play only a minor role in the determination
of consistency."*

This conclusion suggests that the same situation may hold true for
catsups in the range of tomato solids in which they are manufactured.
It would certainly corroborate the belief that every effort should
be made to obtain maximum pectinic acids retention.

The method of measuring consistency of these tomato pastes
was the modified Penetrometer described by Underwood and Keller (1948).
Although several objective methods have been proposed for catsup,
the one which is of interest to the manufacturer is the Bostwick
Consistometer, upon which U. S. Standards for grading are based.
This instrument is fully described by Kertesz (1951).

Considerable importance is attached to solids by the manufacturer,
and while no data are available in the literature, the effect on
consistency is noted. The solids include both the tomato solids, and
other solids in the formula. There are no set standards concerning the
proportions of these items in the formula, except for the minimum

* "Factors Influencing the Quality of Tomato Paste II. Pectic Changes
value of tomato solids, which is 12 per cent in the United States.

The manufacturer considers the most important consistency factor in the formula to be the ratio of tomato solids to sugar (Schoenfeld, 1950). It is sometimes the practice to vary this ratio in an attempt to arrive at a desired consistency; the higher the ratio, the better the consistency, when the same total solids end point is used. If such control of consistency can be obtained without significantly varying the quality of product, it deserves further investigation as to the quantitative relationships. But a considerable variation in sugar involves other considerations. The purpose of sugar in the formula is principally to counteract the tart flavor imparted by the vinegar, which in turn acts as a preservative. From the standpoint of flavor, then, attention should be paid the ratio of sugar to acid, which should be reasonably constant. If the sugar in the formula is changed, it should be necessary to change the acid too. But this would affect the keeping quality of the catsup, and the whole process may not be feasible.

The effect of insoluble solids on consistency is noted by the manufacturer through the use of screens in the cyclones, shaker screens, and finishers. It is recognized that the use of fine screens results in a product which is smoother, since it contains smaller insoluble particles; the product, however, has a poorer consistency. Conversely, wider screen openings give a coarser product of better consistency. In general, the screen sizes are fixed by a given manufacturer, although they may sometimes be changed to control speckiness.
To summarize, the literature survey shows the following facts which are pertinent to the problem of consistency control:

1. The general factors which govern the consistency of catsup are pectinic acids content, formula, and screen sizes used in manufacture.

2. Good retention of pectinic acids are attained in catsup manufacture by inactivating the pectic enzyme system in the macerate with a "hot break" temperature of 185°F. In addition, a minimum of heat exposure during processing results in greater retention.

3. The contribution of pectinic acids to consistency in a given catsup sample is probably due to the effect on viscosity of the serum by the dispersed fraction. Additional fractions are found in the insoluble particles of tomato solids and as insoluble salts. Whether the latter fractions contribute to the consistency other than as suspended particles is not known.

4. The pectinic acids dispersed in the serum may be determined in a hot water extract. When determined as calcium pectate, that portion will be indicative of the high molecular weight pectinic acids which contribute to the viscosity of the serum, and the consistency of the catsup.

5. The consistency factor of the pectinic acids in the serum may be varied for study by the addition of pectinic acids and by enzymatic degradation of the naturally occurring pectinic acids.

6. The formula of the catsup affects the consistency principally through the quantity of tomato solids and the quantity of added sugar. The former contributes pectinic acids and other solubles to the serum, and the insolubles which are suspended therein. The latter probably contributes to consistency through its own increase in the relative
viscosity of the serum. The extent to which normal variations in the formula affect consistency is not known.

7. The screens used by the manufacturer control consistency through their effect on the amount of insolubles suspended in the serum, and the size distribution of these insolubles. The extent to which normal variations in screen sizes affect consistency is not known.

In the absence of sufficient quantitative data in the literature from which the relative importance of the variables may be judged, the procedures used in relating them are developed progressively.
EXPERIMENTAL WORK

I. Investigation into the Quantitative Effect of Pectinic Acids Content on a Single Sample of Commercial Catsup

Introduction:

Although the importance of pectinic acids content with respect to consistency is recognized, there is no available data to indicate quantitatively the degree of importance, when consistency is measured by the Bostwick Consistometer. The investigations of McColloch, Nielsen, and Beavens (1950) indicate that consistency of tomato paste is influenced to a far greater extent by variations in total pectic substances than a total solids variation of 2.8 per cent or an insoluble solids variation of 1.1 per cent. It might therefore be expected that pectinic acids content would be the most significant factor in commercial catsups which possess a similar degree of variation in solids.

In order to make pectinic acids the sole variable in a single sample, the incorporation of commercial pectin, and the enzymatic degradation of naturally occurring pectinic acids, should produce a variation in consistency which is indicative of the importance of pectinic acids.

Determination of the pectinic acids in the hot-water extract as calcium pectate should show a close correlation with consistency. The consistency readings of the Bostwick Consistometer inversely show increasing or decreasing consistency. Both methods are fully described in the Appendix.

Procedure:

A large composite sample of commercial catsup was made. To 400 gram portions, a dispersible pectin (sodium salt) was added in concentrations
of 0.075 and 0.100 grams per hundred grams of catsup. To another portion, an unmeasured quantity of approximately one gram of pectin was added. The pectin was added by sprinkling small amounts on the surface and stirring in while heating on a water bath, such that all the pectin was incorporated when the bulk temperature of the catsup was 70°C. The portions of catsup were covered to prevent evaporation and held for one week, mixing thoroughly at intervals to insure the dispersion of the added pectin.

The consistency of each portion was measured, and the total pectic substances in the hot water extract determined as calcium pectate.

To two other portions of the catsup, a highly active pectinase preparation was added to a concentration of 0.05 per cent, and incubated at 30°C. After four days, consistency and calcium pectate was determined on one portion. After one week, the same determinations were made on the other portion.

Results:

<table>
<thead>
<tr>
<th>Portion</th>
<th>Consistency (cm.)</th>
<th>Per Cent Calcium Pectate</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Added pectin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.100 g./100 g.</td>
<td>5.4</td>
<td>0.432</td>
</tr>
<tr>
<td>0.075 g./100 g.</td>
<td>5.7</td>
<td>0.344</td>
</tr>
<tr>
<td>ca. 1 g. added</td>
<td>6.1</td>
<td>0.540</td>
</tr>
<tr>
<td>B. Master sample</td>
<td>5.4</td>
<td>0.425</td>
</tr>
<tr>
<td>C. Degradated 4 days</td>
<td>7.6</td>
<td>0.066</td>
</tr>
<tr>
<td>Degradated 1 week</td>
<td>8.2</td>
<td>0</td>
</tr>
</tbody>
</table>
Discussion of Results:

The data for the catsup portions containing added pectin are significant in that the added amount apparently did not show up in the calcium pectate determination to the extent that it was added. Furthermore, no improvement in consistency was noted over the master sample, but rather, a loss of consistency took place. It appears that no uniform relationship between consistency and calcium pectate can be obtained through addition of a foreign pectin, although the reason for this discrepancy is not evident.

The degradation of the naturally occurring pectinic acids shows a marked effect on consistency; a 2.8 centimeter loss of consistency is obtained by decreasing the calcium pectate value from 0.412 per cent to zero.

The partially degraded portion shows consistency and calcium pectate values between those of the master sample and the zero value. It appears that some relationship might exist between consistency and the pectinic acids of the hot water extract. By obtaining more sets of values between the initial value and complete degradation, the nature of this relationship should be clearer.

An important conclusion concerning the effects of solids on consistency can be made from the results. The consistency factor of calcium pectate is not as significant in this catsup as the conclusions of McColloch would suggest. Thus, catsups meeting the minimum requirements of 12 per cent tomato solids may have a consistency of 10 centimeters or more. In order to obtain general data relating the
factors affecting consistency, different values of tomato solids must be used. In addition, the effect of variations in formula and of screen sizes must be investigated.

Conclusions:

1. The addition of foreign pectin to effect variation of catsup consistency is not satisfactory for this investigation.

2. The degradation of naturally occurring pectinic acids in catsup in order to measure the consistency factor of the hot-water extract, may be accomplished through the use of a highly active pectinase preparation.

3. The pectinic acids content of the hot-water extract is not the only significant factor affecting consistency, and an interrelationship with normal variations in formula and screen sizes must exist.
II. Investigation into the Relative Importance of Variations in Formula as Affecting Consistency

Introduction:
Considerable attention is paid by Schoenfeld (1950) to the ratio of tomato solids to sugar in influencing consistency; the effect of vinegar, salt, spices, and onions is considered negligible. Normally the latter factors contribute less than nine per cent solids, mostly soluble. It seems reasonable that this relatively small amount of substances, mostly dissolved, would have little effect on consistency, since they would contribute little to the relative viscosity of the serum. On the other hand, sugar is normally present in concentrations ranging between fifteen and twenty per cent, and sometimes greater. This large amount of a relatively large molecule should be somewhat greater in effect on serum viscosity. Tomato solids contribute to consistency through the insoluble portions and through the dissolved substances, especially pectinic acids. By increasing the ratio of tomato solids to sugar, it would be expected that consistency would be improved, although there is no indication in the literature to suggest how much this would be.

In the manufacturing process, especially where the product is concentrated in open kettle to the desired end point, variation of the solids to sugar ratio results in a product in which the level of tomato solids and sugar have both been varied. In order to perform an experiment in which the consistency effect may be fairly evaluated, it is desirable to hold constant either tomato solids or sugar. In this experiment, tomato solids have been held constant; variation of tomato solids is dealt with in a separate experiment.
Procedure:

Laboratory catsup was made from commercial tomato paste. In order to adjust tomato solids in the catsup, the total solids of the paste was determined by drying in the vacuum oven. A sodium chloride determination showed that the paste did not contain added salt, and the total solids value was taken as tomato solids. A predetermined value of tomato solids was arrived at by weighing out the ingredients in the mixing vessel and adjusting with distilled water. In this experiment, fifteen per cent tomato solids was used throughout.

Four preparations were made. The first contained only tomato solids, and the second contained tomato solids with salt and vinegar. The third and fourth contained tomato solids, vinegar, salt, and sugar at two levels. The consistency of each preparation was measured.

Results:

<table>
<thead>
<tr>
<th>No.</th>
<th>Tomato Solids (%)</th>
<th>Salt (%)</th>
<th>Vinegar (grain)</th>
<th>Sucrose (%)</th>
<th>Consistency (cm.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>7.5</td>
</tr>
<tr>
<td>2</td>
<td>15.0</td>
<td>3.4</td>
<td>11.2</td>
<td>--</td>
<td>7.4</td>
</tr>
<tr>
<td>3</td>
<td>15.0</td>
<td>3.4</td>
<td>11.2</td>
<td>18.9</td>
<td>6.0</td>
</tr>
<tr>
<td>4</td>
<td>15.0</td>
<td>3.4</td>
<td>11.2</td>
<td>25.0</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Discussion of Results:

Comparison of preparations 1 and 2 shows a consistency factor of 0.1 centimeter for the salt and acid. This factor is not significant in view of an expected deviation of 0.2 centimeters for consistency measurements. It may therefore be expected that a few per cent additional solids in flavor extractives from spices and onions would
have a negligible effect upon consistency.

Comparison of preparations 2, 3, and 4, however, show that sugar has a considerable influence on consistency. It is seen that inclusion of 18.9 per cent sugar improves consistency by 1.4 cm., or a slope of 13.5 per cent sugar per centimeter. Between 18.9 and 25.0 per cent sugar, consistency is improved 0.5 cm., or a slope of 12.2 per cent sugar per centimeter.

Although all other factors were held constant at arbitrary levels, the order of magnitude of the consistency factor of sugar under these conditions points to some definite conclusions. The variation in the sugar level itself could not be a fruitful method of adjusting consistency, for a change in excess of ten per cent is required to adjust the consistency one centimeter. Hence, the variation of the tomato solids to sugar ratio must principally be one of the variation in tomato solids, the sugar being varied only to attain the same total solids end point.

This group of data also indicates that a sugar variation of 2.5 per cent in either direction is required to produce a significant variation of plus or minus 0.2 centimeters in consistency measurements. Thus, data for the catsup of 18.9 per cent sugar content should not differ significantly in consistency for catsups between the limits of 16.4 per cent and 21.4 per cent. This fortuitous situation allows the formula to be fixed in other experiments, thus reducing the number of significant variables. It should be possible to obtain general data relating tomato solids, consistency, and pectic acids content that would be applicable for moderate variations in sugar, salt, spice, vinegar, and onion level.
Conclusions:

1. The contribution to consistency of salt and vinegar is shown to be insignificant. From this it is concluded that the consistency contribution of the extractives from spices and onions would be negligible.

2. Variation of the ratio of tomato solids to sugar is, in effect, the variation of tomato solids alone. The variation in sugar is made in order to arrive at the same total solids end point.

3. A variation of two to three per cent sugar is required to produce any significant variation in consistency.

4. Data obtained for consistency of laboratory catsup, where tomato solids and pectinic acids are the only variables, would be applicable to catsups in general, should the additional factor of screen sizes prove insignificant. If the effect of screen sizes is significant, no such general data could be obtained in the laboratory.
III. Investigation into the Relationship between Consistency, Pectinic Acids Content, and Tomato Solids, Through Controlled Degradation of Pectinic Acids

Introduction:

It was indicated in Section I. that values relating consistency to the calcium pectate value could be obtained for a single sample by enzymatically degrading the pectinic acids, and making determinations between the initial and zero values.

It was also concluded that tomato solids have a considerable influence on consistency, and the relationship between pectinic acids and consistency should be obtained at different levels of tomato solids. By fixing the levels of sugar, vinegar, and salt in the formula, the data obtained would not differ significantly for reasonable variations in formula of these factors.

The use of a single tomato paste in making laboratory catsups is in effect, the fixing of screen sizes, thus holding this factor constant. The data obtained can then be compared with other catsups in order to determine whether screen sizes have a significant effect upon consistency.

The minimum value of tomato solids in catsup is 12 per cent, while commercial catsups generally contain about 15 per cent. A normal range of variation, then, may be taken as between 12 and 16 per cent.

Procedure:

The formula for laboratory catsup was fixed at 18.9 per cent sucrose, 3.4 per cent salt, 11.2 per cent vinegar (50 grain, distilled), and a range of tomato solids from 12.0 to 16.0 per cent.

A controlled degradation of a single catsup was accomplished as follows: The ingredients were weighed into a 6" x 8" battery jar with a closely fitting wooden cover, such that 2500 grams resulted. The
catsup was kept homogenous by inserting a shaft driven by a 1/8 horsepower electric stirrer, to which was attached a large, high pitch stainless steel propellor. A coil of 20 feet of 3/16 inch tygon tubing on the outside of the jar carried cooling water which was adjusted to keep the catsup temperature slightly below 65°F., in order to facilitate consistency measurements. To the initial charge of catsup the pectinase preparation was added to a concentration of about 0.05 per cent, after making initial measurements of consistency and calcium pectate.

Samples were withdrawn at various intervals during the digestion, and consistency and calcium pectate determined. Additional enzyme was added in order to hasten complete degradation.

Two runs were made; one at either end of the tomato solids range. The tomato paste used in both runs was the same. The source was a commercial paste packed in a No. 10 can, and did not contain added salt. The total solids by vacuum oven was used to adjust the tomato solids in the catsups.

Results:

<table>
<thead>
<tr>
<th>Consistency (cm.)</th>
<th>Per Cent Calcium Pectate</th>
<th>Consistency (cm.)</th>
<th>Per Cent Calcium Pectate</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.6</td>
<td>0.425</td>
<td>5.0</td>
<td>0.453</td>
</tr>
<tr>
<td></td>
<td>0.385</td>
<td></td>
<td>0.417</td>
</tr>
<tr>
<td>9.5</td>
<td>0.261</td>
<td>5.3</td>
<td>0.447</td>
</tr>
<tr>
<td></td>
<td>0.255</td>
<td></td>
<td>0.432</td>
</tr>
<tr>
<td>9.9</td>
<td>0.246</td>
<td>5.7</td>
<td>0.352</td>
</tr>
<tr>
<td>11.4</td>
<td>0.079</td>
<td>6.3</td>
<td>0.253</td>
</tr>
<tr>
<td>11.5</td>
<td>0.038</td>
<td>6.4</td>
<td>0</td>
</tr>
<tr>
<td>11.9</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Discussion of Results:

The lower level of tomato solids was intended to be 12.0 per cent, but a check determination on the total solids of the paste made it necessary to revise the value to 11.7 per cent.

An examination of the data shows that a uniform relationship is not followed, even though the trend is evident. This is especially shown by the 16.0 per cent sample. While the precision of the data do not fully justify this conclusion, observations made during the experiment lead to the conclusion that the sets of values determined during the digestion do not represent true conditions in catsup. As the digestion proceeded, the physical characteristics of the acetone precipitate changed markedly. Initially flocculent and voluminous, it became progressively powdery and granular. However, the consistency dropped off rapidly even though calcium pectate values were high. This indicates that the action of the pectinase is to rapidly produce low molecular weight fractions which contribute little to the consistency. There is no basis to assume that the action of degrading factors in catsup manufacture would be similar in action to this enzyme preparation. It is therefore concluded that the only valid results of this experiment are the initial and zero values.

It is seen from the results that the consistency factor is greater at 11.7 per cent tomato solids than at 16.0 per cent. Because of this difference, it would be desirable to ascertain values at tomato solids levels between 11.7 and 16.0 per cent.
Conclusions:

1. The significance of tomato solids in determining consistency of catsup is confirmed.

2. A valid relationship between consistency and calcium pectate cannot be obtained by following the digestion of pectinic acids in a single sample. However, the initial and zero values may be taken as valid.

3. The consistency factor of pectinic acids appears to be greater at lower values of tomato solids. Some physical relationship is indicated.
IV. Investigation into the Relationship Between Consistency, Pectinic Acids Content, and Tomato Solids

Introduction:

By using the same approach as in Section III., and determining only initial and zero values for catsups at different levels of tomato solids, a set of data may be obtained which would indicate the quantitative relationship between all variables except the screen sizes.

In addition, by obtaining points at different levels of pectinic acids, this data could be broadened to permit the drawing of curves which would be indicative of the physical situation.

Procedure:

Catsups were made at intervals of 1.0 per cent between 12.0 and 16.0 per cent.

In the first group of catsups, two sets were made. In one set, the catsup at each level of tomato solids was weighed out to include 0.05 per cent of the pectinase preparation. These 400 gram portions were incubated at 30°C. for one week, and consistency was measured.

In the other set, catsups at the same intervals of tomato solids were made, except that pectinase was not included. These catsups were held one to five days at 37°F., after which determinations were made for consistency and calcium pectate.

All catsups in the first group were made using the same tomato paste. Two other groups of catsup were made from two different tomato pastes. All pastes used were made by the same manufacturer.
Results:

<table>
<thead>
<tr>
<th>Per Cent Tomato Solids</th>
<th>12.0</th>
<th>13.0</th>
<th>14.0</th>
<th>15.0</th>
<th>16.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Set 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistency (cm.)</td>
<td>8.9</td>
<td>7.5</td>
<td>6.5</td>
<td>5.6</td>
<td>4.9</td>
</tr>
<tr>
<td>Per cent calcium pectate</td>
<td>0.230</td>
<td>0.238</td>
<td>0.255</td>
<td>0.287</td>
<td>0.314*</td>
</tr>
<tr>
<td>Wt. calcium pectate/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wt. tomato solids</td>
<td>0.0192</td>
<td>0.0198</td>
<td>0.0182</td>
<td>0.0191</td>
<td>0.0196*</td>
</tr>
<tr>
<td><strong>Set 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistency (cm.)</td>
<td>11.3</td>
<td>10.0</td>
<td>8.5</td>
<td>7.3</td>
<td>6.3</td>
</tr>
<tr>
<td>at complete degradation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistency (cm.)</td>
<td>9.6</td>
<td>8.1</td>
<td>7.1</td>
<td>6.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Per cent calcium pectate</td>
<td>0.199*</td>
<td>0.216*</td>
<td>0.212</td>
<td>0.251</td>
<td>0.286</td>
</tr>
<tr>
<td>Wt. calcium pectate/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wt. tomato solids</td>
<td>0.0166*</td>
<td>0.0166*</td>
<td>0.0152</td>
<td>0.0167</td>
<td>0.0179</td>
</tr>
<tr>
<td><strong>Group III</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistency (cm.)</td>
<td>9.3</td>
<td>--</td>
<td>6.7</td>
<td>5.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Per cent calcium pectate</td>
<td>0.224*</td>
<td>--</td>
<td>0.262*</td>
<td>0.280*</td>
<td>0.299</td>
</tr>
<tr>
<td>Wt. calcium pectate/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wt. tomato solids</td>
<td>0.0187*</td>
<td>--</td>
<td>0.0187*</td>
<td>0.0187*</td>
<td>0.0187*</td>
</tr>
</tbody>
</table>

* Not a direct determination. Calculated from a determination on the tomato paste used.
Discussion of Results:

The tabulated results show a high degree of correspondence. Only one set of zero values was determined; however, the 16.0 per cent zero value of 6.3 cm. agrees with that obtained in Section III.

An examination of the ratio of weight calcium pectate to weight tomato solids, which places catsup and tomato paste on a common basis, shows that although the three pastes used differed in the level of pectinic acids, this difference was not marked. This failure to obtain points over a wider range hinders the drawing of curves. It is seen that for any level of tomato solids, an infinite number of curves could be drawn through the data points. However, when these points are all plotted on the same graph, and when the initial and zero values from Section III. are included, a collation of the entire set of data can be made that enables the drawing of a representative set of curves. This is because a fairly definite trend can be observed in the average slopes. The curves drawn for the data are shown in Figures 1 and 2.

Even if the data points were only connected with straight lines, an important consideration is still evident. While the consistency factor of these representative levels of pectinic acids is considerable, the importance of tomato solids is of greater significance.

The data points also show quantitatively the amount of tomato solids required to obtain a desired consistency between definite limits of pectinic acids retention.

Assuming that the drawn curves closely represent the physical situation, an insight into interrelationships between these three variables is gained. This is more evident by plotting the data in a third form in which the ordinate is per cent tomato solids, as in Figure 3.
The first situation which is evident from the drawn curves is that the consistency factor decreases with increasing tomato solids. This would not be expected, in view of the fact that consistency is considered proportional to viscosity. However, at low values on the Bostwick Consistometer, this relationship evidently breaks down. This is reasonable, for if it were not so, a consistency of zero centimeters could conceivably be obtained at a higher level of tomato solids of perhaps 25 per cent.

The data values of Figure 2 are transferred down to Figure 3 to produce this important plot. Different levels of calcium pectate ratio are arbitrarily used to draw in the curves. It is readily observed that the actual data points for zero consistency follow a smooth curve, thus supporting the belief that a true physical situation is represented. As the level of calcium pectate is increased, the tendency is to become asymptotic to the ordinate. Stated in terms of the variables, the principle of diminishing returns holds for both pectinic acids retention and for increasing tomato solids levels.

For a given set of screen sizes, for which this data was obtained, Figure 3 is of great practical significance, and represents the type of data which is sought in this report. It shows the per cent tomato solids which a formula must contain in order to obtain a desired consistency. For any given manufacturing process, the degree of pectinic acids retention may be assumed to be substantially constant. Once this degree of retention is determined, the corresponding curve on this graph fixes the formula for any desired consistency. Any change in pectinic acids retention, shown by plant laboratory checks, merely entails shifting to a different curve to obtain the tomato solids needed.
Furthermore, by enzymatically digesting the pectinic acids in a line sample of the product, the corresponding consistency shows from the curve the per cent tomato solids. This may be used as a check on standardization accuracy; present methods of determining tomato solids involve a tedious set of chemical determinations, with doubtful results.

Conclusions:

1. The combined importance of pectinic acids content and tomato solids level in determining consistency is quantitatively confirmed.

2. Increasing pectinic acids retention and increasing the level of tomato solids in the formula, independently act to improve consistency, such that the improvement can be quantitatively described.

3. The improvement factors of pectinic acids or tomato solids is not in direct proportion to their increase; this effect becomes increasingly important at low readings on the Bostwick Consistometer. This phenomenon is due to the nature of the instrument.

4. In a manufacturing process in which screen sizes and pectinic acids retention are fixed, a graphical relationship can be obtained which relates the tomato solids in the formula required to produce a desired consistency. Such data is adaptable to changes in pectinic acids retention.

5. In a manufacturing process in which screen sizes are fixed, the enzymatic digestion of the pectinic acids of a line sample followed by a consistency determination, can be used in conjunction with a similar graphical relationship as a convenient check on tomato solids level.
V. Investigation into the Importance of Screen Sizes in Influencing Consistency

Introduction:

The amount and size distribution of suspended particles in the catsup serum is determined by the treatment in cyclones, shaker screens, and finishers. By passing through screens possessing openings of various sizes, the large insoluble portions are either removed or are further broken up. Inasmuch as the characteristics of the suspended particles are uniquely determined by a processing arrangement, the quantitative effect of this variable cannot be estimated in this report.

If, however, the significance of the screen sizes is great, it should be noted in the failure of commercial catsups to agree with the data obtained for a fixed value of screen sizes. In order to allow fairly for such a discrepancy, catsups can be chosen which are judged to be smoother or coarser than the laboratory catsups. Should such observed variation in catsup smoothness fail to show significant discrepancies in consistency data, it would be evidence that screen sizes may be relatively unimportant.

Procedure:

It was recalled that data was obtained for an unknown catsup sample in Section I. Two other catsups were chosen; all three were smoother in appearance than the laboratory catsup.

Consistency and calcium pectate were determined on the catsups. The pectinic acids were digested and the zero values of consistency determined. This data was then compared with the plotted data obtained in Section IV. as follows:

1. A working diagram similar to Figure 3 was made from Figure 1, drawing the curve at the determined level of per cent calcium pectate.
2. From this curve, the per cent tomato solids corresponding to the determined consistency was determined.

3. From Figure 3, the tomato solids corresponding to the zero consistency was determined. This value was compared with that obtained in 2.

Results:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Consistency (cm.)</th>
<th>Per Cent Calcium Pectate</th>
<th>Corresponding Tomato Solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>5.4</td>
<td>0.412</td>
<td>15.1</td>
</tr>
<tr>
<td></td>
<td>8.2</td>
<td>0</td>
<td>14.2</td>
</tr>
<tr>
<td>II.</td>
<td>6.1</td>
<td>0.136</td>
<td>15.3</td>
</tr>
<tr>
<td></td>
<td>7.6</td>
<td>0</td>
<td>14.8</td>
</tr>
<tr>
<td>III.</td>
<td>5.2</td>
<td>0.312</td>
<td>15.8</td>
</tr>
<tr>
<td></td>
<td>8.1</td>
<td>0</td>
<td>14.3</td>
</tr>
</tbody>
</table>

Discussion of Results:

The results clearly indicate a significant discrepancy between the data obtained for these test samples and that obtained on laboratory catsup. As shown in Section II, this discrepancy is probably not due to differences in formula values of sugar, vinegar, salt, or spices. The remaining factor is therefore the differences due to screen sizes.

In addition to this method of comparison, the data points for the test samples may be plotted on Figure 1. In doing so, it is noted that the consistency factor due to pectinic acids in these samples is greater than that in the laboratory catsup.
The fact that the laboratory catsup was observed to be coarser than the test samples of commercial catsup further implicates the screen factor. It seems reasonable to believe that the product which contains more coarse material would be held together better, and flow slower, than the one which is smoother and contains much fine material.

Conclusions:

1. The screen sizes used in manufacturing of catsup exercises a significant effect upon consistency. The magnitude of this effect is not known.

2. Data obtained in the method described in IV. can be applicable only when determined on, and applied to, a particular manufacturing process.
SUGGESTIONS FOR FUTURE WORK

The experimental work shows that data relating consistency with pectinic acids retention and tomato solids level must be obtained for a given manufacturing process in which the formula and screen sizes are fixed. Observations made in the experimental work show that a rapid, and perhaps a more accurate method, might be used to relate the degree of pectinic acids retention to consistency. It appears that the volume of acetone or alcohol precipitate in the hot-water extract is an index of the consistency factor of the pectinic acids. A standard determination might be developed in which the acetone precipitate is rapidly determined in a volumetric container by centrifuging. Should such a method prove feasible, it would be more applicable to quality control determinations than would be the tedious calcium pectate determination.
APPENDIX
EXPERIMENTAL TECHNIQUES

Consistency

The Bostwick Consistometer was used for all consistency measurements. This instrument consists of a metal trough set on threaded legs, so that the floor may be raised or lowered to level. A short distance from one end is a sliding gate which divides the main body of the trough from the space into which the material being tested is filled. A trigger device holds the gate closed until the measurement is made; pressing the trigger releases the gate rapidly and allows the material to flow into the trough. The bottom is etched into 0.5 centimeter divisions, starting from the gate.

In making a consistency measurement on catsup, the material is first adjusted to a temperature of 68°F. It is then filled into the space provided until just before overflowing. The excess is stripped off once using a straight knife blade or spatula. Holding the instrument tightly, the trigger is squeezed. At the end of 30 seconds the far end is tipped up to halt the flow. The center reading and two corner readings are made to the nearest tenth of a centimeter. (It was found advisable to extend the etchings on the instrument up the side of the trough in order to facilitate corner readings.) The consistency measurement is taken as the arithmetic average of the three readings.

The precision varies with consistency, being higher at lower values. However, an expected deviation of 0.2 centimeters may be taken to cover the normal range of variation in catsup consistency.

In all experiments, at least four determinations were made on a single sample. At least eight were taken for catsups with poor consistency.
Pectinic Acids

The total pectic substances were determined in the hot water extract as calcium pectate. The method used was adapted from the procedure recommended by Kertesz. The procedure given below was used in obtaining most of the data. The same procedure was used to yield calcium pectate precipitates of five to ten times greater weight; in this case the quantities used were inconveniently large. It was found most convenient to take a large sample and make the filtrate up to 500 ml., taking aliquots for duplicate results.

1. A sample of 50-100 grams is weighed into a 250 ml. beaker. About 5-10 grams of filter aid is added to the beaker. Boiling distilled water is added to make the total volume about 230 ml., and the mixture is made homogenous using a glass stirring rod with a rubber policeman.

2. The mixture is filtered by vacuum on quantitative filter paper. The cake is washed repeatedly with small portions of hot distilled water until a volume of at least 200 ml. is used.

3. The filtrate is transferred to a 500 ml. volumetric flask, and made up to volume with distilled water. If the determination is on tomato paste, 5 ml. of 1.0 N. acetic acid is included.

4. A 50-100 ml. aliquot is pipetted into a beaker, and twice the volume of pure acetone is added dropwise with vigorous stirring. The beaker is covered and allowed to stand overnight.

5. The precipitate is filtered out on quantitative filter paper and is washed with about 100 ml. of 67% acetone, and finally, with pure

acetone. The precipitate is never allowed to dry on the paper.

6. The acetone precipitate is dissolved through the filter paper into the original beaker using hot distilled water. It is advisable to use the rubber policeman to aid in the solution of the material.

7. After the solution has cooled to room temperature, 50 ml. of 0.2 N. sodium hydroxide is allowed to run through the filter paper and funnel into the solution. The resulting solution should be about 150 ml. It is mixed thoroughly and allowed to stand at least twenty minutes, but preferably overnight. Apparently a twenty minute saponification is sufficient, but a more readily filterable precipitate is obtained if it is allowed to continue overnight.

8. Thirty ml. of 1.0 N. acetic acid are added with stirring. After standing a few moments, 5 ml. of 2M. calcium chloride is added dropwise with vigorous stirring. Then 15 ml. more are added.

9. The mixture is heated to boiling and is filtered by suction on quantitative filter paper. It is never allowed to dry on the filter. It is washed throughout with small volumes of hot distilled water until a volume of at least 200 ml. is used.

10. The precipitate is transferred to a 25 ml. glass Gooch crucible with a fritted glass bottom that has been dried at 100°C. and weighed. The transfer is accomplished with the aid of a rubber policeman and wash bottle.

11. The precipitate is drained as dry as possible. The crucible is placed in a 100°C. air oven for at least twelve hours. It is cooled in a desiccator and weighed.

Because the determination is long and tedious, not enough repeat determinations were made on a single sample to evaluate the precision.
but it should be comparable to the method of Carre and Hanes, which is reported to have a range of 5 to 10 per cent.

**Total Solids**

Total solids was determined in a vacuum oven after a procedure given in *Methods of Analysis, A.O.A.C.* Samples of 3 to 6 grams were weighed into dried aluminum dishes. The samples were placed in a vacuum oven and the temperature adjusted to 70°C. A vacuum of 15 inches of mercury was used for the first hour, and 30 inches for four additional hours.
DATA AND CALCULATIONS

Determinations were all typical, and the calculations uncomplicated.

The following specific examples cover all variations.

Consistency and Calcium Pectate on a Single Sample

(Data from 12% catsup sample—Section IV—Group II)

Consistency measurement:

<table>
<thead>
<tr>
<th>Center reading</th>
<th>Corner reading</th>
<th>Corner reading</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5</td>
<td>8.8</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>9.2</td>
<td>9.1</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>9.3</td>
<td>8.8</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>9.5</td>
<td>8.9</td>
<td>8.7</td>
<td></td>
</tr>
<tr>
<td>9.2</td>
<td>8.6</td>
<td>8.6</td>
<td></td>
</tr>
</tbody>
</table>

Calcium pectate determination:

Wt. sample 185.458
74.536
110.992

Wt. calcium pectate

\[
\begin{align*}
29.7581 & \quad 29.8352 \\
29.7046 & \quad 29.7868 \\
0.0535 & \quad 0.0484 \\
\hline
22.184 & \quad \text{Av.} = 0.0510
\end{align*}
\]

Per cent calcium pectate = \( \frac{0.0510 \times 100}{22.184} = 0.230 \)

Ratio: Wt. Calcium pectate = \( \frac{0.230}{12.0} = 0.0192 \)

Adjustment of Tomato Solids in Catsup Sample

(Data from 12% sample—Section IV—Group III)

Total Solids of Tomato Paste

Wt. sample and wt. dry solids

\[
\begin{align*}
4.010 & \quad 2.045 \\
1.390 & \quad 1.390 \\
2.620 & \quad 0.655
\end{align*}
\]

Per cent tomato solids = \( \frac{0.655 \times 100}{2.620} \approx 25.00 \)

(5 other determinations: 24.99, 24.97, 24.90, 25.09—mean value = 24.99)

Therefore, in 390 grams of catsup containing 12.0% tomato solids—

\[
\frac{0.12 \times 300}{24.99} = 144.1 \text{ grams of tomato paste}
\]
18.9% sugar in 300 grams of catsup = 56.7 grams
11.2% vinegar " " " " 33.6 grams
3.4% salt " " " " 10.2 grams
12.0% tomato solids required \( \frac{144.1}{244.6} \) grams

Therefore require 55.4 grams distilled water to adjust paste to correct solids.

**Calcium Pectate Determination on Tomato Paste**

(Asterisked values in Results of Section IV--Group I, 16.0% sample)

Calcium pectate determined on paste--

Per cent calcium pectate = 0.506

Ratio: \( \frac{\text{Wt. calcium pectate}}{\text{Wt. tomato solids}} = \frac{0.506}{25.84} = 0.0196 \)

Calculation--calcium pectate in catsup made from paste.

Per cent calcium pectate = 0.0196 x 16.0 = 0.314
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