1944

A study of methods of preparation and containers for canned tomato juice and factors influencing its quality.

Rubie Alfreda Woodward
University of Massachusetts Amherst

A Study of METHODS of PREPARATION and CONTAINERS FOR CANNED TOMATO JUICE AND FACTORS INFLUENCING ITS QUALITY

WOODWARD 1944

A STUDY OF METHODS OF PREPARATION AND CONTAINERS FOR CANNED TOMATO JUICE AND FACTORS INFLUENCING ITS QUALITY

Rubie A. Woodward

Thesis submitted for degree of

Master of Science

Massachusetts State College, Amherst

May, 1944

TABLE OF CONTENTS

INTRODUCTION

The ease of production of tomatoes in the home garden and their adaptability for canning as well as their popular flavor are factors which have contributed to the importance of tomato juice as a home-canned product. In addition canned tomato juice provides an important source of vitamin C for many persons. By the same token a large volume of tomato juice is canned commercially every year.

At the present time several methods for the home preparation and canning of tomato juice are being advocated by different agencies. To date little, if any, information is available concerning the effect of these different methods on the ultimate quality of juice and ascorbic acid content of the product. There are at least seven different types of jars and cans being used for home-canned tomato juice as well as three types of containers for commercial products.

It was the purpose of this investigation to evaluate several methods of preparation and different types of containers as to their effect on the quality of canned tomato juice, as adjudged by color, flavor, vitamin C content, and keeping quality during storage. Recommended methods of preparation and types of containers for canned tomato juice have been outlined.

This investigation was extended to include a study of the use of d-iso ascorbic acid as an antioxidant for tomato juice. Preliminary data indicated that this compound is a good anti-oxidant for vitamin C.

During the course of the present investigation factors contributing to the formation of a white sediment in canned tomato juice were investigated. This sediment is occasionally found in both commercial and home-canned juices. Preliminary evidence indicated that it is caused by the action of enzymes on certain of the pectin compounds found in tomatoes and that it may be controlled by varying the temperatures at which the juice is extracted.

REVIEW OF LITERATURE

Home-Canned Tomato Juice

Hess and Unger (1919) found only a slight loss of vitamin C after one year's storage of canned tomatoes. Clow and Marlatt (1930) reported similar findings, and also reported that tomatoes canned by the open kettle method and fed to guinea pigs within nine months were not so potent as those canned by the cold pack method. The latter they claimed were as rich a source of vitamin C as fresh, raw tomatoes.

LaMer, Campbell, and Sherman (1921) found that boiling for one hour destroyed practically 50 percent and for four hours 70 percent of the antiscorbutic vitamin present in tomato juice.

Delf (1924) reported that a sample of bottled tomatoes which was stored for six months had lost two-thirds of its antiscorbutic potency. After storage for nearly four years, a further but smaller loss was found to have taken place. The following year Delf (1925) observed that tomato juice canned in tin and stored for four years at laboratory temperature, required 10 ml. as a protective dose for guinea pigs. This was an estimated loss of about 80 percent since fresh juice required approximately 2 ml. to protect against scurvy. He also attempted the use of 0.09 percent sodium sulfite as a preservative of the antiscorbutic value. This was distasteful to the test animals, also results seemed to show that the higher percentage of sulfite was not conducive to the preservation of antiscorbutic values of the juice.

The same year Kohman, Eddy, and Carlsson (1924) presented data to show that oxidation is the major factor causing destruction of vitamin C and that it is relatively stable toward heat.

Kohman, Eddy, and Zall (1930) found that seven grams of green tomatoes, raw or canned were about the equivalent in vitamin C content to five grams of ripened tomatoes, raw or canned. Kohman (1931) and Kohman, Eddy, and Gurin (1933) applied the principle of deaeration and anaerobic handling to the manufacture of tomato juice. Where freshly prepared juice was quickly heated to boiling in shallow layers, the inert gases present scrubbed out the oxygen and most of the vitamin C in the juice was retained. When tomato juice was prepared by a method which avoided beating air into it, there was less destruction of vitamin C than in "cycloning" the juice. Air, which may later destroy vitamin C, is apparently not beaten into the juice during cycloning while it is hot. The atmosphere of steam present under that condition appears to provide a protective envelope.

Results of a study of the antiscorbutic potency of the juice of raw and of home-canned tomatoes that were cold packed and processed twenty minutes as reported by Spohn (1931) indicated a considerable loss of vitamin C in the canned product. Three to five ml. of raw tomato juice were sufficient to protect guinea pigs used in the tests from scurvy, while four ml. of juice of canned tomatoes failed to protect the animals from onset of the disease.

Kohman (1931) found that crushing tomatoes releases enzymes which destroy vitamin C, which, in the sound plant cell, is relatively stable.

Hicks (1931) found that juice packed without treatment to remove air was absolutely lacking in vitamin C. Vacuum sealing did not appear to be particularly effective in removing the air from the juice itself. Vacuum treatment of the juice before bottling, combined with vacuum sealing, proved most effective in preserving the vitamin C content in the final product.

Barnby and Eddy (1932) observed that if proper precautions in the manufacture of tomato juice were taken, the vitamin C content could be conserved in the final product. There should be no loss in manufacture. They found no difference in the ascorbic acid content of the same batch of tomato juice canned in either glass or tin containers.

Fellers, Clague, and Isham (1935) reported that the juices obtained by straining home-canned or commercially canned tomatoes through a seive were protective to guinea pigs at the three to four ml. levels and compared favorably with the best commercial brands of canned tomato juice.

Daniel and Rutherford (1936) reported that both home canning and storing of tomato juice have a significant destructive effect upon its ascorbic acid content. Both factors cause approximately the same percentage loss of ascorbic acid in whole tomatoes and juice canned in tin. Storage destroyed a greater percentage of the vitamin C in the juice than in the whole tomatoes in glass containers. Average total losses due to both canning and storage under different conditions ranged from 21 to 55 percent of the original ascorbic acid content of juice extracted from fresh tomatoes.

Maclinn and Fellers (1938) found no appreciable loss in vitamin C in canned tomato juice during a storage period of 121 days.

Tressler and Curran (1938) reported that ascorbic acid is not lost more rapidly from tomato juice packed in bottles filled completely than from the juice in cans similarly filled. After 40 days little or no loss of ascorbic acid occured during further storage of tomato juice either in bottles or in cans which were completely filled with hot juice.

Hauck (1938) found that the vitamin C loss in tomato juice is greater when it is stored in glass than in tin containers. The latter juice had twice the ascorbic acid content of the former. The reduced ascorbic acid of freshly opened tomato juice in tin was more stable than samples from the same lot of juice canned in glass. The former lost approximately 25 percent of its reduced ascorbic acid when stored in the refrigerator for four days after opening.

Rogers and Mathews (1938) reported that commercial and home-canned tomatoes each contained 0.14 mg. of ascorbic acid per gram. They found that guinea pigs receiving four ml., which according to chemical test contained from 0.55 to 0.56 mg. of ascorbic acid, were completely protected from scurvy. The results correlated closely with the findings of Sherman (1922) that 0.5 mg.

of vitamin C is necessary for full protection of a guinea pig over a ninety day period.

Sandborn (1938) reported that contamination of tomato juice by air results in a loss of vitamin C, color, and flavor.

Kertesz (1938) re-emphasized the value of the "hot break" method of extracting tomato juice because of its effectiveness in inactivating enzymes.

Maclinn and Fellers (1938) stored tomato juice in plain and amber glass containers under dark and conditions of normal exposure to light. There was a small continuous loss of ascorbic acid in the plain glass containers whether stored in light or dark. Amber glass inhibited losses up to a period of at least 80 days.

Kardo-Sysoeva and Nisembaum (1938) reported that the presence in tomatoes of a stabilizer, contained largely in the pulp, inhibited the oxidation of vitamin C by oxygen. The small part of this stabilizer that passes into solution might be completely inactivated by boiling but the remainder that was in the pulp was only partially destroyed by boiling.

The following year Abbott (1939) found that home-canned tomato juice and tomatoes contained 14 to 17 mg. ascorbic acid per 100 ml. of juice and was equivalent to the vitamin C present in five commercial brands of tomato juice. Juice canned by sterilization in a water bath gave the lowest values for ascorbic acid.

McElroy, Munsell, and Steinberger (1939) reported that canning tomatoes by either the hot pack or cold pack method caused no significant loss in their ascorbic acid content. An increase in the processing time in the cold pack method did not effect the vitamin C. Tomatoes canned in glass jars and stored for 6 months at room temperature, either in sunlight or in the dark, lost approximately the same amount of ascorbic acid.

Collier, Morrison, and Morse (1941) reported that glass packed tomatoes were high in ascorbic acid; however, when they were packed in tin, ascorbic acid was retained to a higher degree because of reducing conditions attributed to the tin plate.

That same year Fellers and Buck (1941) reported that tomato juice after one year's storage lost 10 to 25 percent of its vitamin C. Very little loss occurred after the first 2 to 3 months' storage.

<u>Commercial Canned Tomato Juice</u>

Kohman, Eddy, and Zall (1930) found that some loss in vitamin C content occurred during the concentration of tomato juice to puree, but that this loss was not proportional to the degree of concentration. The tomato concentrate was richer in vitamin C weight by weight than the original tomato juice.

It was reported (anomymous (1931)) that oxidation during the commerical manufacture of canned tomato juice and ketchups is particularily destructive to vitamin C. Vitamin C potency was maintained both by regular canning methods, and by concentration in an open kettle to 2.5 volume or greater. Concentration "in vacuo" did not influence the vitamin C. However, in this latter method it was necessary to avoid preliminary admission of air.

Fellers, Clague, and Isham (1935) found that the protective dosages for the prevention of scurvy in guinea pigs of eight samples representing five brands of commercially canned tomato juice varied from two to more than six grams. No significant differences in the vitamin C content were found between the natural and the homogenized juices. The concentrating of tomato juice by open kettle method destroyed approximately 50 percent of the original vitamin C value. Juice with a poor flavor was found to have less vitamin C than that of a good flavor.

The following year Daniel, Kennedy, and Munsell (1936) found that in general poor brands of commercial tomato juice were also low in vitamin C, containing 12 mg. per 100 ml. while other brands contained about 18 mg. per 100 ml.

Tressler and Curran (1938) conducted experiments on the relation of headspace to the destruction of ascorbic acid in commercially bottled tomato juice. They found that destruction of the vitamin C in storage was proportional to the amount of oxygen in the container.

McElroy and Munsell (1939) found that commercially canned tomato juice showed no significant loss in ascorgic acid value when stored in loosely covered containers in a refrigerator for four days. Juice prepared from commercially canned tomatoes and from fresh tomatoes and stored under same conditions showed significant losses of this vitamin after two days storage.

D-iso Ascorbic Acid as an Antioxidant

Zilva (1935) reported that d-iso ascorbic acid has one twentieth the antiscorbutic activity of l-ascorbic acid.

Yourga (1943) studied color development in solutions of d-iso ascorbic acid and l-ascorbic acid and found that the amount of color formed was proportional to the amount of oxygen available in the headspace and to the temperature at which bottled solutions were stored. L-ascorbic acid developed color more intensely than did d-iso ascorbic acid. This showed an added advantage in the use of d-iso ascorbic acid over l-ascorbic acid as an antioxidant.

Yourga confirmed the previous findings that d-iso ascorbic acid had one twentieth the antiscorbutic value of l-ascorbic acid.

This author also found that at 26°C. the difference in rates of oxidation of l-ascorbic acid and d-iso ascorbic acid was small but discernable. At first there was no difference, but as the length of storage increased, the dye value of d-iso ascorbic acid dropped below that of l-ascorbic acid. At 60°C. marked differences in the rates of oxidation of l-ascorbic acid and d-iso ascorbic were noted. D-iso ascorbic acid disappeared at a considerably faster rate than l-ascorbic acid in bottled aqueous solution. By means of biological tests with bottled solutions of l-ascorbic acid, d-iso ascorbic acid and mixtures of the two, it was demonstrated that because of its more rapid rate of oxidation d-iso ascorbic acid is an effective anti-oxidant for l-ascorbic acid (vitamin C).

EXPERIMENTAL PROCEDURE

A. Effect of methods of preparation and canning on the quality of home-canned tomato juice. There have been a variety of methods suggested for the preparation and canning of tomato juice. These fall into three groups -- "cold extraction" of juice, "hot extraction" of juice, and juice from canned tomatoes. "Cold extracted" juice is that obtained from cold, unheated tomatoes or from tomatoes which have been given only a slight holding period in hot water prior to expressing of juice. "Hot extracted" juice is that which is obtained from tomatoes which are heated to boiling prior to extraction of the juice. Juice prepared by this method is of better consistency because more pectin is extracted and retained. Another advantage ascribed to the latter method is that it gives a greater yield of juice. The heating breaks down the cell walls to some extent thus allowing more liquid to be pressed from the fruit. In the former method many cells remain intact during the extraction procedure, thus giving a smaller yield.

The canning of whole tomatoes may be done by either a "hot pack" or "cold pack" method. That is, the tomatoes may be heated to boiling prior to putting into jars, or may be placed into jars immediately after peeling. The former method is believed to cause a greater loss of ascorbic acid because of the longer time of exposure of the fruit to air.

Different processing times have been suggested for home-canned tomato juice. In this work fifteen and thirty minutes processing times in a boiling water bath were used.

The various methods of preparing "cold extracted" juice, "hot extracted" juice, and cold and hot packed tomatoes are outlined below. It was hoped that from the data obtained from this study, that a conclusion could be made as to whether "cold extraction" of juice, "hot extraction" of juice, or hot or cold packed tomatoes would give a better quality juice, and which particular procedure for this method is best.

Experiments were also conducted in relation to the preparation of fresh tomato juice. Both hot and cold extractions were used in order to determine which procedure would yield the best quality juice.

In all cases fifteen jars of each type of canned tomato juice or canned tomatoes were prepared.

1. Cold extraction. Two methods of cold extraction were used. In the first, *"cold break" number one, the tomatoes were thoroughly washed and allowed to stand in boiling water $1\frac{1}{2}$ minutes. They were then immediately plunged into cold water to cool. After draining, coring, trimming, and quartering, they were pressed through a food strainer or seive fine enough to hold back the seeds and skins. The resultant juice was filled immediately into quart lightning jars to within one quarter inch of the top. One teaspoonful of salt was added to each of the jars, which were then sealed and processed in boiling water. One half of the jars was processed for 15 minutes and the other half was processed for 30 minutes.

"Cold break" number two was carried out the same as "cold break" number one except that the tomatoes were not given the holding period in boiling water. Both 15 and 30 minute processing times were used for this method.

2. Hot extraction. For the "hot break*" method the tomatoes were washed well, and cores and any green or spoiled portions were removed. The tomatoes were cut into pieces (quarters), placed in a kettle, heated to boiling, and allowed to simmer until softened. The hot softened tomatoes were immediately pressed through a seive fine enough to hold back the seeds and skins. The resultant juice was reheated just to boiling and put immediately into quart lightning jars to within one quarter inch of the top. One teaspoonful of salt was added to each of the jars, which were then sealed and processed 30 minutes in boiling water.

Three different types of seives were used in preparing one batch of "hot extracted" tomato juice to determine the difference, if any, in the destruction of vitamin C with different strainers. These were (1) the regular food strainer seive, (2) a cone-shaped seive with a wooden paddle, and (3) a dilver type seive as shown in plate I.

The effect of homogenization was also studied in the case of the "hot extracted" juice. The tomato juice was put through a small home type homogenizer before being reheated to boiling.

---

*"Cold break" juice is that which is extracted from cold, unheated tomatoes."Hot break" juice is that which is extracted from tomatoes which have been heated to boiling.

3. Tomato juice from home-canned, hot packed tomatoes. The tomatoes were washed well and dipped into boiling water for about one minute, or until the skins cracked. They were then plunged into cold water, drained, peeled and cored promptly. After heating to boiling in a kettle, they were packed immediately into one quart lightning jars to overflowing. One teaspoonful of salt was added to each jar. The jars were sealed and processed for 15 and 30 minutes in boiling water.

4. Tomato juice from home-canned, cold-packed tomatoes. The tomatoes were prepared as if for "hot pack" except that they were not heated prior to putting into the jars. After peeling they were placed immediately into quart lightning jars to within one quarter inch of the top. One teaspoonful of salt was added to each jar, which was sealed immediately and processed, some for 15 and some for 30 minutes, in boiling water.

The ascorbic acid content of the fresh tomatoes and juice immediately before packing was determined by the indophenol dye titration method. (Maclinn and Fellers (1938)). The ascorbic acid content of the canned tomato juice was determined immediately after processing and after four, six and eight months' storage at room temperature. In all cases ascorbic acid determinations were made on three different jars of tomatoes or juice. After eight months' storage the color and flavor were noted. The results of the vitamin C determinations are shown in Table 1 and data on color and flavor in Table 2.

5. The effect on ascorbic acid destruction and quality of different methods of preparing fresh tomato juice. Three methods of preparing fresh tomato juice were used. In method number one the tomatoes were washed well, cored, and cut into quarters or eighths depending on the size of the tomatoes. They were then rubbed through a food strainer fine enough to hold back the skins and seeds. The juice was filled into quart lightning jars with one teaspoonful of salt per jar, and placed in a refrigerator for six hours to chill.

For method number two the tomatoes were washed well and allowed to stand in boiling water for one minute, then dropped into cold water to cool. They were then treated as in method number one. The juice was put into quart lightning jars with one teaspoonful of salt per jar, and placed in a refrigerator for six hours to chill.

Method number three was a "hot extraction". The tomatoes were washed well, cored, trimmed, and quartered. The pieces were placed in a kettle, heated to boiling and allowed to simmer until softened. The hot, softened tomatoes were put through a food strainer. The juice was put into quart lightning jars with one teaspoonful of salt and the jars were sealed and placed in a refrigerator to chill for six hours.

The vitamin C content of the fresh tomatoes and the juice after storage of six hours in a refrigerator was determined. The color, flavor, and consistency were also noted, and the results are presented in Table 3.

B. Effect of types of containers on quality of canned tomato juice. Many different types of containers are now available for the canning of foodstuffs. In the following study tomato juice was canned in 13 different types of home and commercial containers in an effort to discover whether or not the type of container had any effect upon the stability of ascorbic acid in the canned juice. The tomato juice was prepared by the "hot extraction" method and put through a Langsenkamp juicer (commercial method). It was then heated to boiling in a stainless steel steam kettle ad filled immediately in the different type containers leaving a uniform headspace appropriate to the particular container being filled. The containers were sealed immediately and processed for 30 minutes in boiling water.

Types of containers used were both home and commercial canning jars and cans. The home-canning jars were the one quart lightning jar, the one quart mason jar, the one quart modified mason jar, the one quart, two-piece metal cap mason jar, and the 20 oz. re-usable coffee jar. The commercial type containers included the 16 oz. vacuum seal wide mouth commercial jar with both plain tin and enameled caps, number two size, plain tin and fruit enameled tin cans, and 16 oz. vacuum sealed bottles and crown seal bottles with plain cork, glazed paper, and tinfoil liners. (plate II).

The vitamin C content of the fresh tomatoes, and juice immediately before packing was determined. The ascorbic acid content of the canned tomato juice was determined immediately after processing and after four, six, and eight months' storage periods at room temperature. In the case of the canned tomato juice the vitamin C content of the juice from three different containers was determined and the results averaged. There was little or no difference between the three samples tested in most cases. The results are summarized in Tables 4 and 5a and 5 b.

At six and eight months' storage periods the color and flavor of the tomato juice was noted as shown in Table 6.

C. <u>D-iso ascorbic acid as an antioxidant for canned tomato juice</u>. It is well known that during the canning and subsequent storage of canned tomato juice the l-ascorbic acid (vitamin C) is oxidized, thus giving a lower ascorbic acid content of the juice. D-iso ascorbic acid is more readily oxidized than the l-ascorbic acid (Yourga, 1943). It would then appear that if d-iso ascorbic acid were added to tomato juice prior to bottling, that it would be oxidized first by the oxygen present in the container, and in this manner the l-ascorbic acid would be protected. The purpose of this study is to find out if this would actually occur in a food product.

The juice was made by the hot break method and put through a Langsenkamp juicer (commercial method). It was then heated to 88-93°C (190-200°F) in a stainless steel steam kettle and filled into preheated pint bottles which were sealed with crown caps with glazed paper "spots". The bottled juice was processed for 30 minutes at 212°F. The juice was packed in groups of fifty bottles each as follows:

Group 1. Control group - no d-iso ascorbic acid added.
Group 2. 30 milligrams d-iso ascorbic acid added per bottle.
Group 3. 95 milligrams d-iso ascorbic acid added per bottle.

The investigations of Yourga (1943 indicated that the use of 30 mg. of d-iso ascorbic acid per pint bottle of solution would be sufficient as an antioxidant for the l-ascorbic acid present in pure solutions. It was thought advisable to use this amount in some of the tomato juice samples and to use 95 mg. per pint bottle in the other samples. This procedure would cover a range which would include a minimum and maximum or above maximum amount of d-iso ascorbic acid necessary to protect the l-ascorbic acid present. It would also show what the effects of adding too much d-iso ascorbic acid would be, if 95 mg. per bottle were too much.

After processing, half of each group was stored for five months at a temperature of 49°C. (120°F.), a severe storage condition. The remaining bottles were stored at 23.9 - 26.7°C (75-80°F.) room temperature for seven months.

Ascorbic acid determinations were made, by the dye titration method as described by Maclinn and Fellers (1938) on the fresh tomatoes, and the juice prior to bottling. The ascorbic acid content was also determined immediately after processing, using three bottles from each sample of juice, and the results, which varied only slightly were averaged. The results of these determinations are shown in Table 7.

At the end of five months' storage period the juice stored at 49°C. (120°F.) was tested by means of the dye titration method (results shown in Table 7) and the twenty-five day weight response bio-assay method (Dunker, Fellers, Esselen (1942). The chemical method indicated the presence of both the vitamin C and the biologically inactive d-iso ascorbic acid. The bio-assay measured only the presence of l-ascorbic acid which is biologically active. The results are shown in Table 8. Table 9 shows that the d-iso ascorbic acid was oxidized before the l-ascorbic acid.

As a check on the indophenol dye titration method the phenylhydrazine method as described by Roe (1944) was also used on a few typical bottles for each sample of tomato juice in this pack. In order to determine whether color, flavor, and vacuum were comparable to vitamin C content, these factors were also noted. The color was graded A, C or substandard by the use of Munsell color discs as prescribed by the Food Distribution Administration for standards.

The results of these determinations are given in Tables 10, 11, and 12.

The juice stored at room temperature was tested at the end of seven months by the dye titration method and also by the bio-assay method to determine the amounts of ascorbic acid and of vitamin C. Results are shown in Tables 13 and 14. Three typical bottles from each sample were tested for color, flavor, and vacuum. These results are given in Table 15.

D. Factors contributing to the development of a white sediment in canned tomato juice. A white sediment occassionally occurs in canned tomato juice, and is particularly noticeable in glass containers. It is thought that the temperature of extraction can be used as a controlling device to produce sediment-free juice. It was the purpose of this study to determine whether a "hot extraction" of juice or a "cold extraction" of juice gave a lighter deposit of white sediment in canned tomato juice.

Tomato juice was prepared by the "cold extraction" and the "hot extraction" methods, canned in pint lightning jars and stored at room temperature in the dark.

After an eight month storage period at room temperature the tomato juice was examined for the amount of white sediment which had been deposited on the bottom of the jars. All of the jars containing "cold extracted" juice had no sediment at all while all the jars containing "hot extracted" juice had a small quantity of sediment in them.

DISCUSSION OF RESULTS

A. Effect of methods of preparation and canning on the stability of vitamin C, color, and flavor of home canned tomato juice. From the results as shown in Table I it may be seen that the method of preparation and canning has an effect on the retention of ascorbic acid in home canned tomato juice. The tomato juice extracted from cold, unheated tomatoes and processed for 30 minutes showed the smallest percentage loss of ascorbic acid during the eight months' storage period, while the juice obtained from cold packed tomatoes which were processed for 15 minutes showed the highest percentage of loss. It may be noted in general that the "cold extracted" juices gave the lowest percentage of loss with the exception of that extracted cold by method number one and processed for 15 minutes.

The latter had a loss of over 50 percent of its original ascorbic acid content, while the other three "cold extraction" methods gave less than a 45 percent loss. In "cold extracted" juice air is trapped in the container. During processing in boiling water there is a considerable amount of venting, or expulsion of air, from them. The jars which were processed for 15 minutes did not vent as much as those processed for 30 minutes, therefore more air was left in them which would tend to allow for greater oxidation of ascorbic acid. "Hot extracted" juice prepared by using the wire sieve gave a loss of 48.1 percent of its original value, while juice extracted from cold packed tomatoes which were processed for 30 minutes gave a slightly higher, but not significantly different loss of 48.8 percent. Extracting the juice hot with the dilver type sieve, the cone type sieve, and homogenizing it, gave losses of over 50 percent. Juice from cold packed tomatoes processed for 15 minutes retained less than 45 percent of its original ascorbic acid. It became necessary to discard the hot packed tomatoes after six months' storage due to spoilage. The juice from them had at this time a very disagreeable flavor, and was thought that insufficient processing time had been used, although a bacteriological study showed the presence of no common spoilage organisms. After four months' storage the retention of ascorbic acid in this pack was nearly as high as that in the cold packed tomatoes and showed promises of being a good method.

The color of the "cold extracted" juice was markedly better than the "hot extracted" juice, or the juice obtained from canned tomatoes as shown in Table 3. The flavor of the juice of all the methods of preparation and canning was good after eight months, except the homogenized juice, which was neither objectionable nor pleasing.

Fresh tomato juice prepared by the "hot extraction" method showed the greatest loss of ascorbic acid but was by far the most desirable product. As shown in Table 4, there was no great loss of ascorbic acid in any of the three methods used for preparing fresh tomato juice. Method number two, which was a cold extraction gave the highest retention in ascorbic acid. It is thought that this may be due to the fact that less time was taken in preparing the juice rather than to the method, itself. Method number one yielded a very pulpy, thick juice resembling a thin ketchup, and was not practical for drinking purposes. Finer particles of pulp were obtained by the second method, but this juice was also thick and undesirable for drinking. A very palatable tomato juice was obtained from the "hot extracted" juice. The particles of pulp were fine, and the consistency was that of good canned tomato juice.

The color and flavor of the juice obtained by all three of these methods was good.

B. Effect of different type containers on the quality of canned tomato juice. From the results shown in Tables 5 and 6 it may be seen that the container itself has quite a significant effect on the retention of ascorbic acid in tomato juice during canning and storing. Of the home type canning jars those with the metal lids are preferable from the standpoint of ascorbic acid retention, to those with the glass lids. These (the former) include the 2 piece metal lid Mason, the zinc P/L Mason and the coffee jar with "63" size metal lid, all of which showed a loss of under 50 percent of the original value of the juice. The quart lightning jar and the quart 3-piece glass lid Mason jar showed a loss of over 55 percent of the original value. Of the commercial containers the plain tin can and the jars and bottles with plain tin caps showed the best retention of ascorbic acid. All of these containers gave a loss of under 45 percent of the original value. The fruit enameled cans, and the jars with lacquered metal lids or with paper "spots" showed the highest loss of vitamin C, or over 50 percent of the original value.

C. D-iso ascorbic acid as an anti-oxidant for canned tomato juice. The results as shown in Table 5, of the determinations on the tomato juice to which d-iso ascorbic was added and stored at 49°C. (120°F.) show that d-iso ascorbic acid is effective as an antioxidant. There was a 20 percent loss of vitamin C in the control bottles, a 10 percent loss in bottles containing 30 mg. of d-iso ascorbic acid per bottle, and no loss of vitamin C in bottles to which 95 mg. of d-iso ascorbic acid had been added.

A weight response curve (figure I) was plotted to show the gain in weight of the guinea pigs receiving .4, .6, and .8 mg. of ascorbic acid per day from the control bottles of tomato juice. From this curve the amounts of ascorbic acid actually fed to the guinea pigs receiving tomato juice from the test samples were determined by comparing the weight r esponses of the test groups with that of the control group. The results are summarized in Table 9 and show that the l-ascorbic acid content of bottled tomato juice was definitely protected from oxidation by the addition of d-iso ascorbic acid. It would appear that the d-iso ascorbic acid, because of its greater affinity for oxygen, took up the oxygen present in the bottle before it could react with the l-ascorbic acid.

The effect of added d-iso ascorbic acid on color and flavor as shown in Table 10 was particularily favorable in the case of the juice to which 95 mg. of th antioxidant had been added. On the whole this juice had good color (only two bottles out of nine showed blackening) and the flavor in all the bottles was good. Blackening of the tomato juice is due to oxidation. This type of blackening is commonly known as "black neck", particularly when it occurs in ketchup. The degree of blackening was closely correlated with the ascorbic acid content of the juice. Tomato juice which showed slight blackening had a higher potency of ascorbic acid than that juice showing more marked blackening. Marked blackening was shown in three bottles, and slight blackening in one bottle out of four, in the sample of juice containing 30 mg. of anti-oxidant per bottle. All four of these bottles had a slight off flavor. The seven control bottles all showed blackening, five were definite, while only two were slight. A slight objectionable off flavor was found in all these bottles. These results compare favorably with those in Table 11 which show that sample number three was by far the best tomato juice as regards color based on the grades of color (U. S. standards for grades of tomato juice, Food Distribution Administration. Processed Food Service, Washington, D. C.) Two bottles out of three were grade A, and one bottle was grade C. Three were no substandard grade bottles. Sample 2 showed no grade A, one grade C, and four substandard grade bottles. The control bottles showed no grade A, 2 grade C, and 2 substandard grade bottles.

The values as obtained for ascorbic acid determined by the Roe method did not correlate closely with those of the dye titration method. According to Roe (1944), there is a greater recovery of ascorbic acid with the phenylhydrazine method than with the dye titration method. In some cases this held true in this study, but for the most part results were lower. Table 12 shows good correlation between the vacuum of the jar and the ascorbic acid content as determined by the dye method. These results indicate that the higher the vacuum the greater the retention of ascorbic acid that is realized.

Table 12, giving the results of ascorbic acid determinations on the juice to which d-iso ascorbic acid had been added and stored for seven months at room temperature, shows that d-iso ascorbic acid can be effectively used as an antioxidant. There was a 20 percent loss of ascorbic acid in the bottles which contained no added d-iso ascorbic acid, and no loss in the two samples which did contain the antioxidant. The color and flavor in all three samples was good. For all practical purposes the flavor of samples number one and two was the same, but sample three tasted more like fresh unheated juice than canned. It was not, however, objectionable.

Due to the loss of a large number of experimental animals because of a lung infection the test for the l-ascorbic acid in this part of the study gave insignificant results. Table 14 gives the results of the gain in weight of the animals which lived to the end of the experiment. From these results it may be seen that those animals on the .6 mg. per day level of ascorbic acid gave fairly close checks. Since it may be assumed that the animals receiving the tomato juice from sample number one were given only l-ascorbic acid, it may be concluded that the animals receiving tomato juice to which d-iso ascorbic acid had been added were also getting only the l-ascorbic acid, and that the d-iso ascorbic acid was oxidized, leaving the vitamin C.

D. Factors contributing to the development of a white sediment in tomato juice. Since all the bottles containing juice extracted by the "cold" method showed no sediment formations, and all those bottles containing juice prepared by "hot extraction" showed a slight sediment at the bottom, it can be said that the temperature of extraction can be used to control the formation of white sediment in tomato juice.

These results confirm those previously obtained by Esselen (1942). It would appear that the sediment observed in the "hot break" juice is possibly an insoluble pectin compound. In the "cold break" juice pectin enzymes present in the raw tomato have an opportunity to break down this insoluble pectin material into a soluble form which does not appear as a sediment in the canned juice. Such an enzymatic breakdown of pectin compounds is indicated by the work of Kertesz (1938), (1939).

Summary and Conclusions

1. The best method of preparing home canned tomato juice, in respect to color and ascorbic acid content, is by "cold extraction" and processing it 30 minutes in boiling water. The tomatoes should be thoroughly washed, and allowed to stand in boiling water for 1½ minutes. They should then be immediately plunged into cold water to cool. After draining, coring, trimming, and quartering, they should be pressed through a food strainer or sieve fine enough to hold back the seeds and skins. The resultant juice should be put immediately into quart jars to within ¼ inch of the top, with one teaspoonful of salt per jar. The jars should be sealed and processed promptly.

2. Fresh tomato juice prepared by a "hot extraction" is the best in flavor, body, and over all desirability. Tomatoes should be thoroughly washed, cored, trimmed, quartered, and placed in a kettle and allowed to simmer until softened. The hot, softened tomatoes should be put through a food strainer and the resultant juice filled into jars with one teaspoon of salt per jar. The jars should be sealed and placed in a refrigerator until served.

3. There is very little difference in ascorbic acid content in tomato juice made with the different type sieves. Juice made with the wire sieve retained

a slightly higher ascorbic acid content, but was not significantly higher.

4. The types of container used in canning tomato juice has a significant effect on the retention of ascorbic acid. Of the home type containers those with metal lids gave best results, and those with glass lids give the least desirable results.

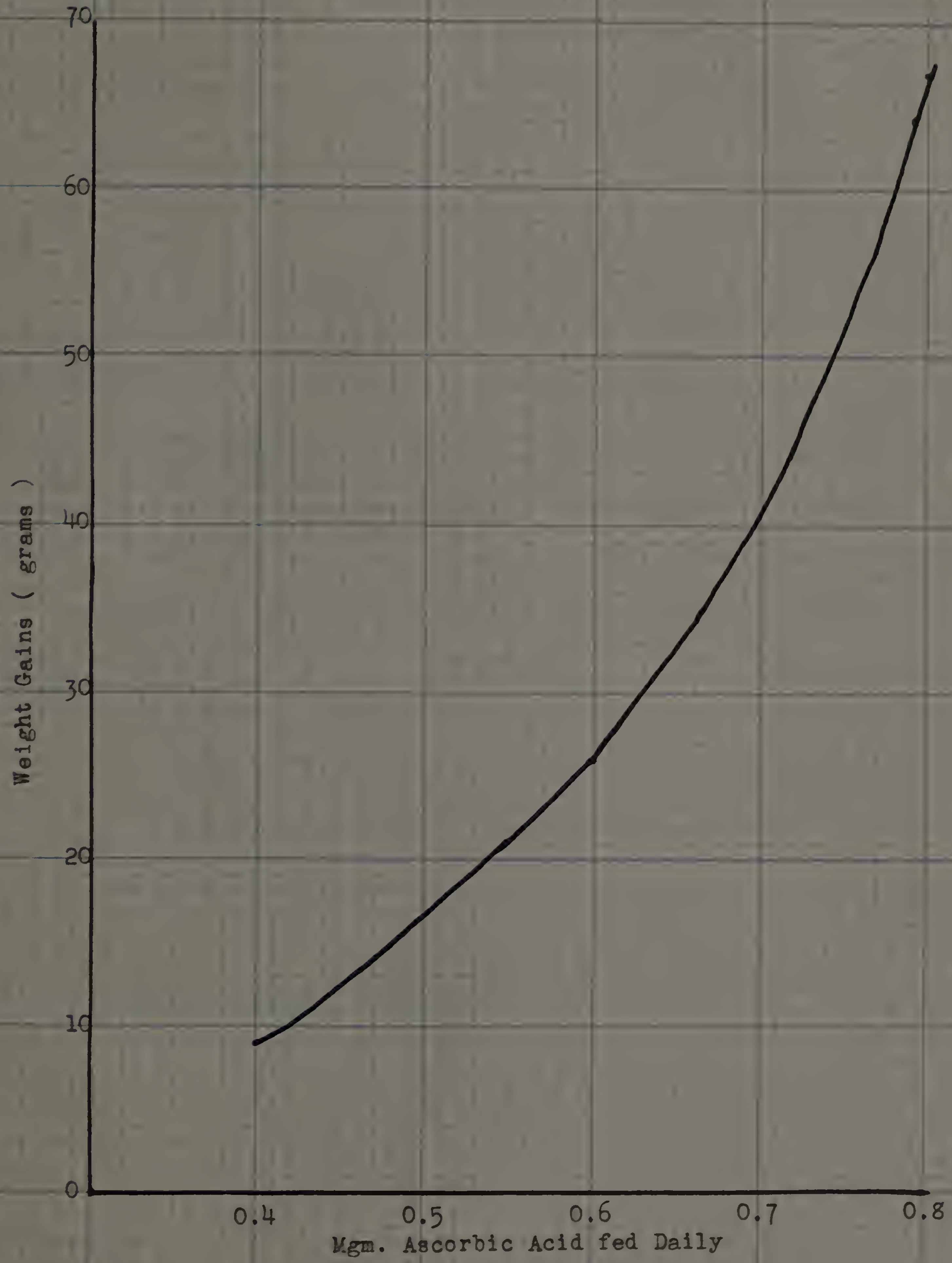
5. Of the commercial type containers plain tin cans and jars and bottles with tin caps or tinfoil liners are the most satisfactory for the retention of ascorbic acid. Fruit enameled caps and jars and bottles with paper spots are less desirable for the retention of ascorbic acid. The higher retention of ascorbic acid found in the jars with plain tin lids can be attributed to the reducing action of the tin plate.

6. D-iso ascorbic acid can be effectively used as an antioxidant in the canning of food stuff where ascorbic acid retention is desired. It would appear that 30 mg. of d-iso ascorbic acid per pint bottle is approximately the optimum amount to add to tomato juice. Bottles containing this amount show retention of ascorbic acid to a marked degree, and resulting juice was pleasing in color, flavor and consistency. The use of a larger amount of d-iso ascorbic acid (95 mg. per pint bottle) provided a marked protection

for the ascorbic acid in the juice but the resultant product had an inferior flavor.

7. The temperature of extraction can be used to govern the formation of a white sediment in canned tomato juice. A "cold extraction" of tomato juice is suggested to give a sediment-free product.

Figure I

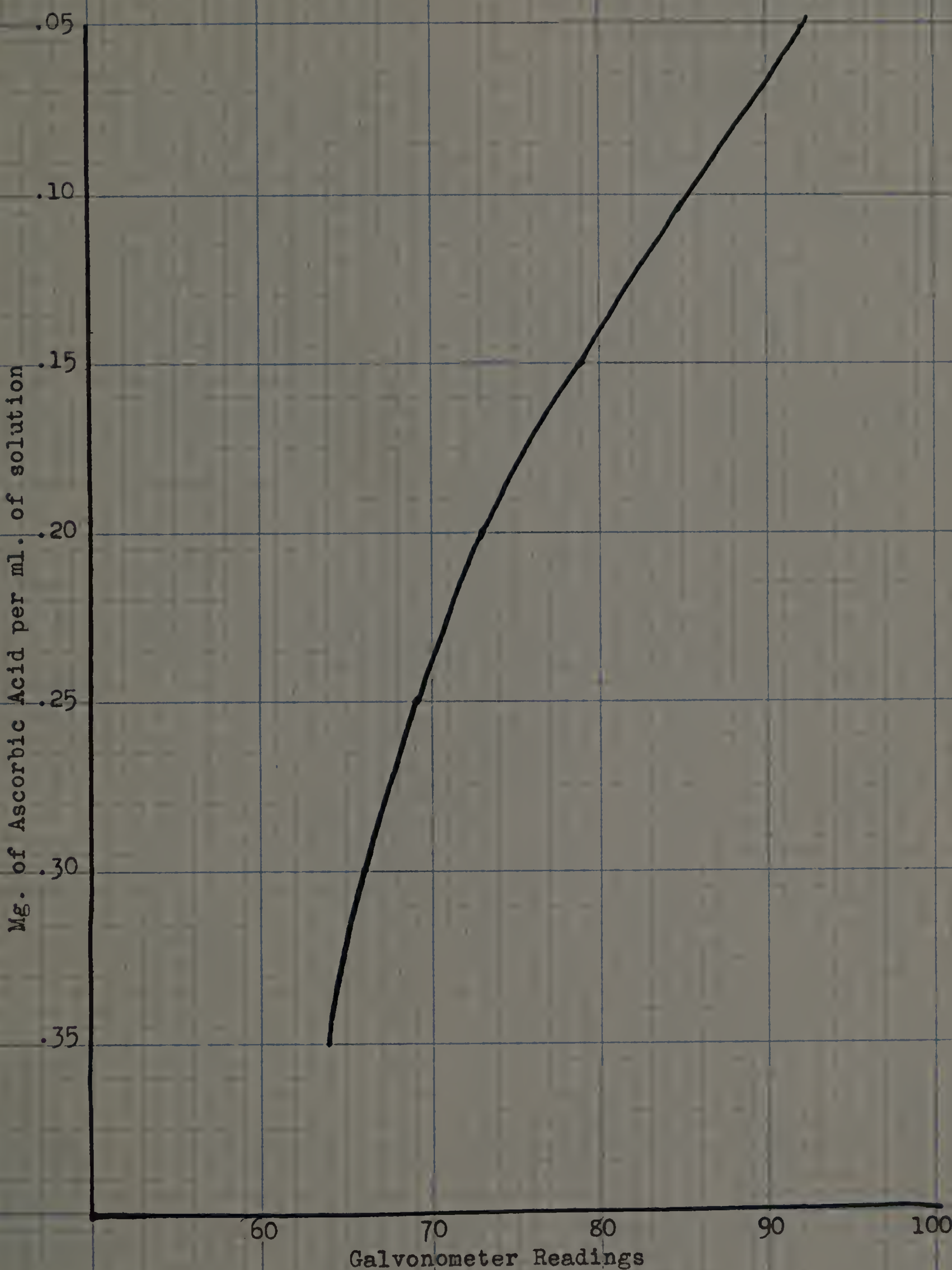


Growth Chart on Guinea Pigs fed Tomato Juice to
which no D-iso Ascorbic Acid
had beeb added

Plate 1. Different Types of Sieves used in Preparation of Home Canned Tomato Juice.

Left to right
1. Dilver type seive
2. Wire seive
3. Cone type seive with wooden paddle

Figure II



Sensitivity of Galvonometer to Solutions
of Ascorbic Acid

Plate 2. Different Type Containers Used for Canned Tomato Juice.

Left to right:

Top row:
- #303 vegetable jar, laquered vacuum cap
- #303 vegetable jar, tin vacuum cap
- Pint crown cap bottle, tinfoil "spot"
- Pint crown cap bottle, glazed paper "spot"
- Pint vacuum seal bottle, tin cap
- Pint vacuum seal bottle, paper liner
- Tin can, plain
- Tin can, fruit enameled

Bottom row:
- Coffee jar, "63" metal lid
- Quart lightning jar, (canned tomatoes)
- Garden queen jar
- Quart, three piece glass lid Mason jar
- Quart, zinc P/L Mason jar
- Quart, two piece, metal lid Mason jar
- Quart lightning jar
- Pint lightning jar (sediment study)

Table 1. Effect of Methods of Preparation and Canning on Stability of Ascorbic Acid on Home Canned Tomato Juice and Tomatoes During Storage.

Ascorbic acid content per 100 ml. of tomato juice.

Methods of Preparation	Process time	Fresh tomatoes per (100 gm.)	Fresh juice	After process	Four months' storage Range	Four months' storage Ave.	Six months' storage Range	Six months' storage Ave.	Eight months' storage Range	Eight months' storage Ave.	Loss of ascorbic acid during eight months' storage. Basis of Original	Loss ... Basis of Storage
	min.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	percent	percent
1. Cold extraction #1	15	37	29	24	18-20	19.0	18-20	19.0	7-15	12.3	54.1	48.7
2. Cold extraction #1	30	27	24	24	17-17	17.0	17-17	17.0	13-16	15.0	37.5	37.5
3. Cold extraction #2	15	29	24	24	16-16	16.0	18-18	18.0	13-15	14.3	40.1	40.1
4. Cold extraction #2	30	27	24	23	19-20	19.6	12-17	13.6	12-15	13.6	43.3	40.9
5. Hot extraction dilver type sieve	30	31	29	25	15-16	15.7	14-14	14.0	11-15	13.6	53.1	45.6
6. Hot extraction cone type sieve	30	31	29	23	16-17	16.3	15-18	16.0	13-15	14.0	51.8	39.1
7. Hot extraction wire seive	30	31	28	25	12-14	13.0	12-14	12.6	13-15	14.0	48.1	44.0
8. Hot extraction homogenized	30	39	27	25	16-17	16.5	16-16	16.0	11-15	12.3	50.3	48.0
9. Hot packed tomatoes	15	42	39	38	26-27	26.3	16 (spoiled)		- -	--	--	--
10. Cold packed tomatoes	15	42	41	40	25-29	27.6	20-21	20.3	12-19	16.6	61.9	58.5
11. Cold packed tomatoes	30	42	41	40	27-27	27.0	20-20	20.0	20-20	20.0	51.2	50.0

Table 2. Effect of Methods of Preparation and Canning on the Color and Flavor of Home-Canned Tomato Juice after Eight Months' Storage.

Method	Processing time	Color	Flavor
Cold extraction #1	15	good	good
Cold extraction #1	30	good	good
Cold extraction #2	15	good	good
Cold extraction #2	30	good	good
Hot extraction, Dilver types sieve	30	fair	good
Hot extraction, cone type sieve	30	fair	good
Hot extraction, wire sieve	30	fair	good
Hot extraction, homogenized	30	fair	fair
Hot pack tomatoes	15	fair	good
Cold packed tomatoes	15	fair	good
Cold packed tomatoes	30	fair	good

Table 3. Effect of Methods of Preparation on Ascorbic Acid Content and Quality of Fresh Tomato Juice.

Mg. per 100 ml. of juice

Method number	Fresh tomatoes	Juice after six hours storage	Quality		
			Color	Flavor	Consistency
	mg.	mg.			
1	39	35	very good	good	Pulpy, course pieces of tomato, thick, settled.
2	39	37	good	good	Finer, thick, not settled, undesirable for drinking but better than juice number 1.
3	39	30	good	good	Fine particles, settled, pleasing not thick.

Table 4. Effect of Containers on Stability of Ascorbic Acid in Canned Tomato Juice During Storage.

Ascorbic acid content per 100 ml. of tomato juice.

Types of container	Fresh tomatoes per 100 gms.	Fresh juice	After processing		Four months' storage		Six months' storage		Eight months' storage		Loss of ascorbic acid during eight months' storage on basis of	
			Range	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	original juice	Storage
	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	percent	percent
1. Quart lightning jar	39.0	32.0	26-26	26.0	16-16	16.0	16-16	16.0	13-16	14.6	54.4	43.8
2. Quart three piece glass lid mason jar	"	"	30-31	30.7	22-22	22.0	--	--	16-16	16.0	50.0	47.8
3. Quart two piece metal lid mason jar	"	"	20-31	30.7	22-22	22.0	19-20	19.3	18-18	18.0	43.7	38.1
4. Quart zinc P/L mason jar	"	"	28-28	28.0	21-22	21.3	18-18	18.0	17-18	17.6	45.0	37.1
5. Coffee jar "63" metal lid	"	"	31-31	31.0	20-22	21.3	19-22	21.0	15-18	16.6	48.1	46.4
6. Pint crown cap bottle tinfoil spot	"	"	28-28	28.0	20-20	20.0	15-17	16.0	15-17	16.3	49.7	47.7
7. Pint crown cap bottle glazed paper spot	"	"	31-31	31.0	19-21	20.3	12-16	14.0	11-16	14.3	55.3	53.8
8. #303 vegetable jar tin vacuum cap	"	"	28-28	28.0	24-24	24.0	20-21	20.3	18-19	18.6	41.9	33.5
9. #303 veg table jar lacquered vacuum cap	"	"	28-28	28.0	23-25	24.0	19-20	19.7	16-16	16.0	50.0	47.8
10. Pint vacuum seal bottle paper liner	"	"	28-28	28.0	24-24	24.0	16-18	17.0	17-18	17.3	45.9	38.2
11. Pint vacuum seal bottle tin cap	"	"	28-28	28.0	23-23	23.0	16-19	18.0	18-18	18.0	43.7	35.7
12. #2 tin can, plain	"	"	31-31	31.0	21-25	23.3	21-23	22.3	18-19	18.6	41.9	40.0
13. #2 tin can, fruit enameled	"	"	31-31	31.0	29-30	23.3	19-21	20.0	14-17	15.0	53.1	51.6

Table 5a. Effectiveness of Different Type Containers on Stability of Ascorbic Acid in Canned Tomato Juice During Eight Months' Storage at Room Temperature. (23.9 - 26.7°C (75 - 80°F)).

Loss of ascorbic acid during storage - based on original juice - effect of canning and storage -

Percent loss

40-45	45-50	50-55	55-60
1. Quart two piece metal lid mason jar. 2. Quart zinc P/L mason jar. 3. #303 vegetable jar tin vacuum cap. 4. Pint vacuum seal bottle, tin cap. 5. #2 tin can, plain.	1. Coffee jar #63 metal lid. 2. Pint crown cap bottle, tinfoil "spot". 3. Pint vacuum seal bottle, paper liner. 4. #303 vegetable jar, lacquered vacuum cap.	1. #2 tin can, fruit enameled. 2. Quart lightning jar. 3. Quart, three piece glass lid mason jar.	1. Pint crown cap bottle, glazed paper spot.

Table 5b. Effectiveness of Different Type Containers on Stability of Ascorbic Acid in Canned Tomato Juice During Eight Months' Storage at Room Temperature. (23.9 - 26.7°C (75 - 80°F)).

<u>Loss of ascorbic acid during storage - based on canned juice immediately after processing-effect of storage only.</u>

<u>Percent loss</u>

30-35	35-40	40-45	45-50	Over 50
1. #303 vegetable jar, tin vacuum cap.	1. Quart zinc P/L mason jar. 2. Pint vacuum seal bottle, paper liner. 3. Pint vacuum seal bottle, tin cap. 4. Quart two piece metal lid mason jar. 5. #2 tin can, plain.	1. Quart lightning jar.	1. Quart three piece glass lid mason jar. 2. Coffee jar #63 metal lid. 3. Pint crown cap bottle, tinfoil spot. 4. #303 vegetable jar, lacquered vacuum cap.	1. #2 tin can, fruit enameled. 2. Pint crown cap bottle glazed paper "spot".

Table 6. Effect of Different Type Containers on Color and Flavor of Home Canned Tomato Juice, during Storage.

Container	Flavor	Color	Flavor	Color
Coffee jar	good	good	good	fair
Quart lightning jar	fair	fair	undesirable	fair
Tin cans, plain	good	good	good	fair
Tin cans, enameled	good	good	good	fair
Pint vacuum seal bottle paper liner	good	good	good	good
Pint vacuum seal bottle tinfoil cap	good	good	good	good
#303 vegetable jar, tin vacuum cap	good	good	good	good
#303 vegetable jar, laquered vacuum cap	good	good	good	good
Pint crown cap bottle, glazed paper spot	fair	good	undesirable	fair
Pint crown cap bottle, tinfoil "spot"	good	good	undesirable	fair
Quart two piece metal lid Mason jar	good	good	good	fair
Quart zinc P/L Mason jar	good	good	good	fair
Quart three piece glass lid Mason jar	good	good	good	fair
Garden Queen jar	----	fair	good	fair

Table 7. Effect of Added D-iso Ascorbic Acid on the Stability of Ascorbic Acid Content of Tomato Juice During Storage at 49°C. (120°F.) and Room Temperature. (23.9 - 26.7°C. (75 - 80°F.)).

Ascorbic acid content per 100 ml. juice

Amount added d-iso ascorbic acid	Fresh tomatoes	Juice before process	Juice after process Range	Juice after process Ave.	After Storage period: 5 months at 49°C. (120°F)	After Storage period: 7 months at (23.9-26.7°C (75 - 80°F))
	mg.	mg.	mg.	mg.		
none	44	25	21-21	21	16	15.5
30 mg. per bottle	44	25	26-29	27	19	21.0
95 mg. per bottle	44	25	37-40	39	23	28.6

Table 8. Effect of Added D-iso Ascorbic Acid in Preventing Loss of L-ascorbic Acid (Vitamin C) and Color and Flavor Changes in Pint Bottles of Tomato Juice During Five Months' Storage at 49°C. (120°F.).

Ascorbic acid content per 100 cc. of juice.

Sample	Amount d-iso ascorbic acid added per bottle	Originally			After 5 months' storage			Percent loss l-ascorbic acid	After storage	
		total	l-ascorbic	d-iso ascorbic	total	l-ascorbic	d-iso ascorbic		flavor	color
	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.		
1	none	21.0	21.0	none	16.0	16.0	none	20.0	off	browned
2	30.0	27.0	21.0	6.0	19.0	19.0	none	10.0	good	good
3	95.0	39.0	21.0	18.0	23.0	21.0	2.0	0.0	fresh	good

Table 9. Effect of Added D-iso Ascorbic Acid in Tomato Juice Fed to Guinea Pigs over a 25-day Period Showing Weight Gains and Actual Vitamin C Fed Daily.

Tomato juice sample	Level ascorbic acid fed per day	Number pigs	Weight gain	Vitamin C fed daily
	mg.		gms.	mg.
1	0.4	2	9	.40
1	0.6	3	26	.60
1	0.8	3	67	.80
2	0.4	3	25	.59
2	0.6	3	64	.79
2	0.8	2	41	.70
3	0.4	3	-14	--
3	0.6	3	28	.62
3	0.8	3	74	.82

Table 10. Effect of Added D-iso Ascorbic Acid on Color, Flavor, and Vacuum of Pint Bottles of Tomato Juice after Storage Period of Six Months at 49°C (120°F).

Amount of d-iso ascorbic acid added per bottle	Number of bottles	color	flavor	Vacuum (one bottle tested)
None	five	definite blackening	slight objectiona ble off flavor	none
	two	slight blackening	slight objectionable off flavor	16.5
30 Mgm.	three	marked blackening	slight off flavor	
	one	slight blackening	slight off flavor	
	four	good	slight off flavor	
95 mgm.	two	slight blackening	good	10.0
	seven	good	good	

Table 11. Effect of Added D-iso Ascorbic Acid in Color of Pint Bottles of Tomato Juice after Storage Period of Six Months.

Amount of d-iso ascorbic acid added per bottle	Total number of bottles	Grade A color	Grade C color	Substandard color
None	four	none	two	two
30 mgm.	five	none	one	four
95 mgm.	three	two	one	none

Table 12. Effect of Added D-iso Ascorbic Acid on the Retention of Ascorbic Acid, as Determined by the Dye Titration Method and the Phenylhydrazine Method.

Mg. of ascorbic acid per 100 ml. juice

Sample	Bottle number	Vacuum	Dye titration method	Phenylhydrazine method
		inches	mg.	mg.
1	a	7.5	12	5.0
1	b	4.0	11	9.0
1	c	Pressure	8	4.0
1	d	0.0	6	9.0
2	a	Pressure	9	7.0
2	b	Pressure	6	7.0
2	c	Pressure	5	6.5
2	d	0.0	9	17.0
3	a	18.0	20	33.0
3	b	18.0	19	17.5
3	c	7.0	15	10.0
3	d	10.0	16	20.0

Table 13. Effect of Added D-iso Ascorbic Acid in Preventing Loss of L-ascorbic Acid (vitamin C) and Color and Flavor Changes in Pint Bottles of Tomato Juice During Seven Months' Storage at Room Temperature. (23.9 - 26.7°C (75 - 80°F))

Ascorbic acid content per 100 cc. juice.

Sample	Amount d-iso ascorbic acid added per bottle	Originally			After 7 months' storage			Loss l-ascorbic acid	After storage	
		total	l-ascorbic	d-iso ascorbic	total	l-ascorbic	d-iso ascorbic		flavor	color
	mg.	mg.	mg.	mg.	mg.	mg.	mg.	percent		
1.	none	21.0	21.0	none	15.5	15.5	none	20.0	good	good
2.	30.0	27.0	21.0	6.0	21.0	21.0	none	none	good	good
3.	95.0	39.0	21.0	18.0	28.6	21.0	7.6	none	fresh	good

Table 14. Effect of Added D-iso Ascorbic Acid in Tomato Juice Fed to Guinea Pigs over a 25-day Period Showing Weight Gains and Actual Amounts of L-ascorbic Acid (Vitamin C) Fed Daily.

Tomato juice sample	Level ascorbic acid fed per day	Number pigs	Weight gain	Vitamin C fed daily
	mg.		gms.	mg.
1	.4	2	42.5	--
1	.6	3	82.0	.60
1	.8	1	104.0	--
2	.4	2	25.0	--
2	.6	3	89.0	.60
2	.8	0	--	--
3	.4	1	48.0	--
3	.6	3	90.0	.60
3	.8	3	--	--
Control ascorbic acid	.4	3	54.0	.40
Control ascorbic acid	.6	1	54.0	--
Control ascorbic acid	.8	3	95.0	--

Table 15. Effect of Added D-iso Ascorbic Acid in Color, Flavor, and Vacuum of Pint Bottles of Tomato Juice after Storage Periods of Seven Months at Room Temperature. (23.9 - 26.7°C (75 - 80°F))

Amount of d-iso ascorbic acid added per bottle	Total number of bottles	Color	Flavor	Vacuum
mg.				inches
none	3	2 good 1 slight blackening	good	19.0 8.5 18.0
30.0	3	good	good	17.0 8.0 11.0
95.0	3	good	fresh	12.0 17.0 18.0

LITERATURE CITED

Abbott, O. D., 1931. Standardization of home canned tomatoes and tomato juice. Fla. Agr. Expt. Sta., Ann. Report. 101. (C. A. 35 : 1531.)

Bailey, E. M., 1938. The vitamin C content of commercially canned tomato juice and other fruit juices as determined by chemical titration. J. Am. Med. Assoc. 110 : 650-651.

Barnby, H. A., and Eddy, W. H., 1932. Tomato juice is tested by a leading vegetable authority. The Glass Packer 11 : 33-34.

Bessey, O. A., and King, C. G., 1933. The distribution of vitamin C in plant and animal tissues and its determination. J. Biol. Chem. 103 : 687-698.

Clow, B., and Marlott, A. L., 1930. Studies of vitamin C in fresh and canned tomatoes. J. Agr. Res. 40 : 767-775.

Collier, B. C., Morrison, M. F., and Morse, M. E., 1940-1941. Ascorbic acid content of some Maritime Province foods. Proc. Nova Scotia Inst. Sci. 20 : 121-126. (C. A. 36 : 1692.)

Daniel, E. P., Kennedy, M. H., and Munsell, H. F., 1936. Relative vitamin C content of orange and tomato juices determined chemically and biologically. J. Home Econ. 28 : 470-474.

Daniel, E. P., and Rutherford, M. B., 1936. Effect of home canning and storage on ascorbic acid content of tomatoes. Food Res. 1 : 341-347.

Delf, E. M., 1924. XC. The antiscorbutic value of fresh and canned English tomatoes. Biochem. J. 18 : 674-678.

Delf, E. M., 1925. XX. The influence of storage on the anti-scurvy value of fruits and vegetable juices. Biochem. J. 19 : 141-152.

Dunker, G. F., Fellers, C. R., and Esselen, W. B., 1942. A comparison of four methods for determining vitamin C with a twenty-five day, weight response bioassay. Food Res. 7 : 260-266.

Esselen, W. B., 1944. Personal Communication.

Fellers, C. R., Clague, J. A., and Isham, P. D., 1935. Value of commercially canned and laboratory-prepared tomato juices as antiscorbutics. J. Home Econ. 27 : 447-451.

Fellers, C. R., and Buck, R. E., 1941. Retention of vitamin C in glass packed foods. Food Res. 6 : 135-141. (C. A. 35 : 5205.)

Gray, P. P., and Stone, I., 1939. New method of preventing rancidity. Food Ind. 11 : 626- 628.

Hauck, H. M., 1028. Vitamin C content of home canned tomato juice. J. Home Econ. 30 : 183-188.

Hicks, C. G., 1931. Research reveals answers to packing and bottling problems. The Glass Container, 10 : 8-9, 22-30.

Kardo-Sysoeva, E. K., and Nisenbaum, R. F., 1939. Changes of vitamin C in tomatoes. Biokhimya 3 : 348-354. (C. A. 33 : 256.)

Kertesz, Z. I., 1938. How pectic enzymes influence the quality of tomato products. The Canner 88 : 1.

Kertesz, Z. I., 1938. Pectic enzymes. II Pectic enzymes of tomatoes. Food Res. 3 : 481-487.

Kertesz, Z. I., 1939. Pectic enzymes. III. Heat inactivation of tomato pectin-methozylase (pectase). Food Res. 4 : 113-116.

Kohman, E. F., Eddy, W. H., and Carlsson, V., 1924. Vitamins in canned foods. II. The vitamin C destructive factor in apples. Ind. Eng. Chem. 16 : 1261-1263.

Kohman, E. F., 1931. Vitamins and tomato juice manufacture. The Canner 72 : 15-17.

Kohman, E. F., 1931. Retaining the tomato vitamins in the manufacture of the juice. Glass Packer 4 : 276-277, 290.

Kohman, E. F., Eddy, W. H., and Gurin, C. Z., 1933. Vitamins in canned foods. XIII. Canning tomato juice without vitamin C loss. Ind. Eng. Chem. 25 : 682-684.

Kohman, E. F., Eddy, W. H., and Gurin, C. Z., 1933. Canning tomatoes without vitamin C loss. Fruit Prod. J. 12 : 299-301.

Kohman, E. F., 1937. Influence of canning procedure on the vitamin C content of tomato juice. The Canner 84 part two : 107-108.

LaMer, V. K., Campbell, H. L., and Sherman, H. C., 1921. The effect of temperature and of hydrogen-ion concentration upon the rate of destruction of anti-scorbutic vitamin. Soc. Expt. Biol. and Med. Proc. 18 : 122. Expt. Sta. Rec. 45 : 563.

Maclinn, W. A., and Fellers, C. R., 1938., 1938. Ascorbic acid (vitamin C) in tomatoes and tomato products. Mass. Agr. Expt. Sta. Bul. No.354 : 17.

McElroy, O. E., Munsell, H. E., and Stienbarger, M. C., 1939. Ascorbic acid content of tomatoes as effected by home canning and subsequent storage, and of tomato juice and fresh orange juice as effected by refrigeration. J. Home Econ. 31 : 325-330.

Roe, J. H., and Oesterling, M. J., 1944. The determination of dehydroascorbic acid and ascorbic acid in plant tissues by the 2, 4 - dinitrophenylhydrazine method. J. Biol. Chem. 152 : 511-517.

Rogers, E. C., Mathews, D. B., 1938. The vitamin C content of Connecticut home canned tomatoes. J. Home Econ. 30 : 114-115.

Sandborn, N. H., 1938. Conservation of vitamin C in tomato juice products. The Glass Packer 17 : 102-103.

Spohn, A., 1931. The antiscorbutic vitamin in the juice of home canned tomatoes. J. Agr. Res. 43 : 1109-1113.

Tressler, D. K., and Curran, K. M., 1938. The causes of loss of vitamin C from bottled tomato juice. J. Home Econ. 30 : 487-488.

Yourga, F. J., 1943. D-iso ascorbic acid and its sodium salt, their properties and practical uses. Doctors Dissertation. Massachusetts State College. 44 pp.

Zilva, S. S., 1935. The behavior of l-ascorbic acid and chemically related compounds in the animal body. Antiscorbutic activity in relation to retention by the organism. Biochem. J. 29 : 1612 - 1616.

Anonymous. 1931. Vitamins in tomato products. Food Manufactures 6 : 7.

Anonymous. 1938. United States standards for grades of tomato juice. Food Distribution Administration : Processed Food Inspection Service, Washington, D. C.

ACKNOWLEDGEMENTS

The author wishes to express her appreciation to Dr. W. B. Esselen, Jr. for his help and guidance in the formulation of this problem. Grateful acknowledgements are also extended to Dr. F. P. Griffith , Mrs. G. M. Cook, Mr. J. Blair, and Mr. J. J. Powers for their careful perusal and valuable criticism of the thesis and to the Glass Container Fellowship Fund which contributed toward making this research financially possible.

Thanks is also extended to Mr. R. G. Tischer for his bacteriological assistance.

Approved by

Francis P. Griffiths

Gladys M. Cook

John H. Blair

Date May 18, 1944