# Concentration and Stability of Ascorbic Acid in Marketed Reconstituted Orange Juice

The examination of 17 brands of reconstituted orange juice showed that the ascorbic acid content decreases at a rate of about 2% per day. An ascorbic acid concentration of 28 mg/100 mL at the labeled expiration date is a reasonable expectation. If the original juice concentrate provides at least 46 mg/100 mL of ascorbic acid in the dilution at the time of preparation, the expected shelf-life to an expiration date value of 28 mg/100 mL is about 20 days.

The susceptibility of vitamin C (ascorbic acid) to oxidation in aqueous solution and the dependence of the reaction on the presence of dissolved and headspace oxygen has been recognized (Bauernfeind, 1953). Lamb (1946) claimed an 8% drop in 6.5 months in the ascorbic acid content of canned orange juice. A study by Kefford et al. (1959) revealed the oxidative destruction of ascorbic acid in canned pasteurized orange juice occurred only during the first few days until the free oxygen disappeared. After this, there was an anaerobic loss of ascorbic acid at a rate of about a tenth of that in the early period. Moschette et al. (1947), in a study of the thermal stability of ascorbic acid, noted a satisfactory retention of the vitamin in canned orange juice stored at 10 °C, but they and others (Brenner et al., 1948) saw a significant destruction of the ascorbic acid at higher temperatures, the rate increasing proportionally with temperature increase. Rakieten et al. (1951) noted little instability of ascorbic acid in frozen orange juice concentrate during frozen storage. However, Anderson and Fagerson (1952) found the ascorbic acid content of frozen orange juice concentrate, as purchased on the retail markets, ranged from 28.7 to 51.5 mg/100 mL of reconstituted juice. Andrews and Driscoll (1977) observed that orange juice, reconstituted according to directions from frozen concentrate and stored in bottles, retained only 82–85% of the original ascorbic acid after 8 days. Berry et al. (1971) and Bissett and Berry (1975), using controlled laboratory conditions, studied the effect of the container type on ascorbic acid retention in reconstituted orange juice and found the losses greater in cardboard containers and polystyrene bottles than in glass and polyethylene containers.

The current popularity and general availability of reconstituted orange juice at the retail level made desirable an investigation of the concentration and stability of the ascorbic acid in these products, under the conditions that prevail as they are offered for sale to the public. Samples of 17 brands of reconstituted orange juices in plastic-coated cardboard containers were collected randomly from refrigerated retail store displays and stored under refrigeration at 4 °C in the laboratory. Results and conclusions relative to the ascorbic acid concentrations and stability are reported. Despite the unknown vagaries of such things as handling and storage conditions, the study yielded information that should be valuable to processors, consumers, and control officials. The study may serve as an example of the type of useful information that can be obtained, even without rigorously controlled experiments which are often not practical in connection with the examination of consumer goods on the market.

## EXPERIMENTAL SECTION

Ascorbic acid determinations were made by the diazotized 4-methoxy-2-nitroaniline method of Schmall et al. (1953) which, in this laboratory, is more rapid than and gives results that agree with those obtained by the official 2,6-dichloroindophenol method (Association of Official Analytical Chemists, 1975).

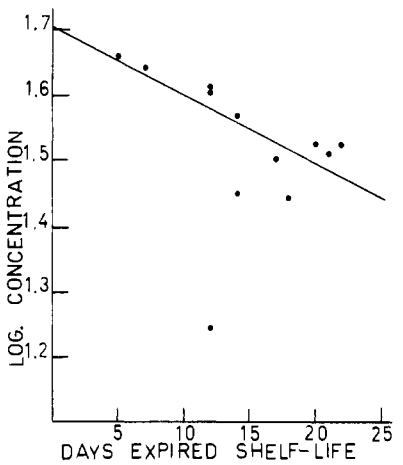


**Figure 1.** Decomposition of ascorbic acid in reconstituted orange juice as a first-order reaction.

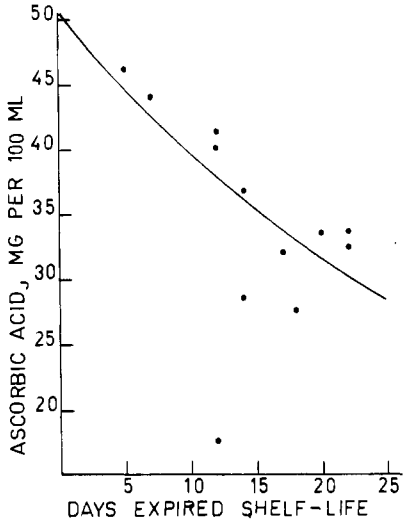


**Figure 2.** Decrease in ascorbic acid concentration of reconstituted orange juice with time.

## RESULTS AND DISCUSSION

Five different processors supplied information about the shelf-lives of their reconstituted orange juices. This information, along with the labeled expiration dates, were used to construct the plot shown in Figure 1 which includes all the data points and the least-squares line calculated from them. A first-order rate process with respect to the ascorbic acid concentration is indicated for the decomposition of ascorbic acid in orange juice. This conforms

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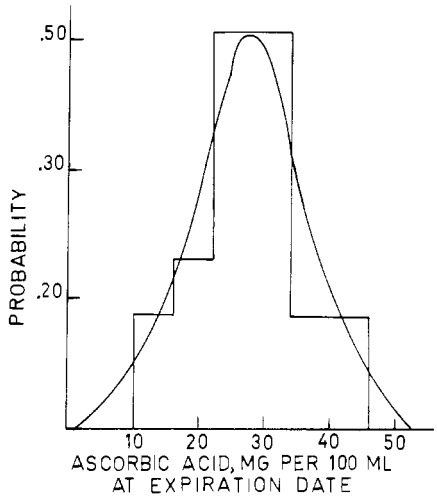


**Figure 3.** Probability curve for ascorbic acid concentration of reconstituted orange juice at the expiration date.

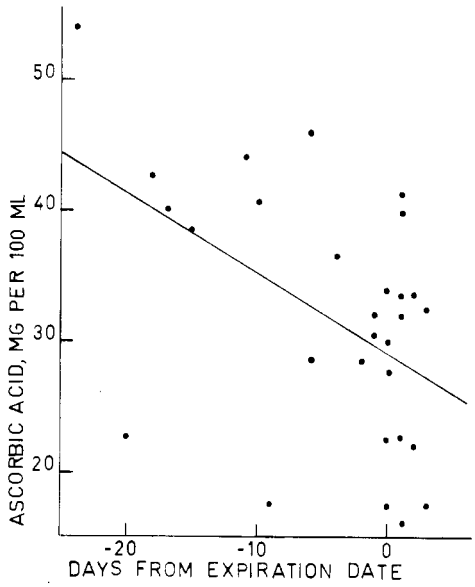


**Figure 4.** Linear regression plot of ascorbic acid concentration of reconstituted orange juice as a function of time relative to the expiration date.

to previous observations that the autoxidation of ascorbic acid is a first-order reaction (Bauernfeind, 1953).

The reaction rate constant calculated from

$$k = (2.303/t) \log (c_0/c)$$

where $c_0$ is the concentration of ascorbic acid at the time of reconstitution of the juice and $c$ is the concentration after time $t$ has elapsed, is 0.02 $day^{-1}$ or a decomposition rate of 2%/day. This is in general agreement with the findings of Andrews and Driscoll (1977). The indicated ascorbic acid content at the time of mixing (zero time) is 50 mg/100 mL. Therefore, the ascorbic acid concentration decreases by 1 mg/day at the time of mixing, and the decrease slows to about 0.6 mg/day at 20 days after mixing, as shown in Figure 2.

Table I contains all the analytical results for samples of orange juice from concentrate, and Figure 3 suggests a basically normal distribution. The ages of the juice samples at their expiration dates, which are included in Table I, were calculated based on Figure 1 data and show an average of 26 days. The average ascorbic acid concentration at the expiration date is 28 mg/100 mL. Figure 4 illustrates an extensive scatter of the ascorbic acid contents of the various samples of orange juice plotted against intervals between the stated expiration dates and the dates of analyses. However, the least-squares line of these data does indicate overall agreement with the latter portion of the Figure 1 curve, in that its slope is −0.6, showing a decrease of 0.6 mg/100 mL of the ascorbic acid per day.

Table II shows the decrease in ascorbic acid obtained by reanalysis of six samples after intervening time periods. The decomposition rate is again 2%/day in each of the individual cases.

Conclusions that are drawn from the results of these studies are: (a) the ascorbic acid concentrations of orange juice from concentrate packed in plastic-coated cardboard containers decreases at the rate of about 2% of the amount present per day, (b) an ascorbic acid concentration of about 28 mg/100 mL at the expiration date is a reasonable expectation (8 fluid ounces of juice with this ascorbic acid content supplies more than the 60 mg U.S. Recommended Daily Allowance), and (c) the ascorbic acid concentration

**Table I. Ascorbic Acid Contents of Orange Juice from Concentrates**

| brand and sample | day analyzed relative to expiration date | ascorbic acid, mg per 100 mL: on day analyzed | ascorbic acid, mg per 100 mL: calcd to expiration date | calcd age of juice at expiration date, days |
|---|---|---|---|---|
| A-1 | +3 | 17.2 | 19.0 | 42 |
| B-1 | 0 | 27.6 | 27.6 | 25 |
| C-1 | −10 | 40.8 | 32.2 | 19 |
| C-2 | −16 | 38.4 | 26.3 | 27 |
| C-2 | −1 | 30.4 | 29.7 | 22 |
| D-1 | 20 | 22.8 | 14.2 | 53 |
| E-1 | 0 | 34.0 | 34.0 | 16 |
| F-1 | −6 | 28.8 | 25.0 | 30 |
| G-1 | −9 | 17.6 | 14.2 | 53 |
| G-2 | −24 | 54.0 | 30.6 | 21 |
| G-2 | +1 | 33.6 | 34.4 | 17 |
| H-1 | −17 | 40.0 | 26.8 | 27 |
| I-1 | +1 | 40.0 | 41.0 | 9 |
| I-2 | −6 | 46.0 | 40.0 | 10 |
| I-2 | +1 | 41.2 | 42.2 | 7 |
| J-1 | −18 | 42.8 | 28.0 | 25 |
| J-1 | +1 | 32.0 | 32.8 | 18 |
| K-1 | −2 | 28.4 | 27.1 | 26 |
| L-1 | 0 | 22.4 | 22.4 | 34 |
| L-2 | 0 | 17.2 | 17.2 | 45 |
| M-1 | +1 | 22.8 | 23.3 | 32 |
| N-1 | +1 | 16.0 | 16.4 | 48 |
| O-1 | 0 | 30.0 | 30.0 | 22 |
| P-1 | +2 | 22.0 | 23.1 | 33 |
| Q-1 | −1 | 32.0 | 31.2 | 20 |
| Q-2 | −4 | 36.8 | 33.5 | 17 |
| Q-2 | +2 | 33.6 | 35.2 | 15 |
| Q-3 | −11 | 44.0 | 34.0 | 17 |
| Q-3 | +3 | 32.4 | 34.8 | 16 |

**Table II. Ascorbic Acid Values for Duplicate Analyses with Days Intervening between Determinations**

| brand and sample | intervening days | ascorbic acid, mg/100 mL: 1st detn. | ascorbic acid, mg/100 mL: 2nd detn. | decomp. rate, %/day |
|---|---|---|---|---|
| C-2 | 15 | 38.4 | 30.4 | 2 |
| G-2 | 25 | 54.0 | 33.6 | 2 |
| I-2 | 7 | 46.0 | 41.2 | 2 |
| J-1 | 19 | 42.8 | 32.0 | 2 |
| Q-2 | 6 | 36.8 | 33.6 | 2 |
| Q-3 | 14 | 44.0 | 32.4 | 2 |

of the original juice concentrate should be such that it provides at least 46 mg/100 mL in the dilution at the time of preparation. If this criterion is met, the expected shelf-life to an expiration date value of 28 mg/100 mL is about 20 days.

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**Sherman R. Squires**
**J. Gordon Hanna***

The Connecticut Agricultural Experiment Station
New Haven, Connecticut 06504

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# Pigmentation and Color Comparison of Ruby Red and Star Ruby Grapefruit Juice

Juice of the Star Ruby grapefruit (*Citrus paradisi Macfad*) extracted by commercial machinery and canned during the regular harvest season contained from 0.34 to 0.56 mg/100 g of β-carotene and 0.57 to 0.72 mg/100 g of lycopene, as compared to the corresponding respective value ranges of 0.09–0.14 mg/100 g of β-carotene and 0.04–0.08 mg/100 g of lycopene for the Texas Ruby Red variety. Blending with Star Ruby juice at about a 30% level in the early processing season and 40% in the late processing season is proposed as a means of maintaining a desired level of pink color in canned Texas grapefruit juice. In Texas, the processing of pink grapefruit juice is emphasized as contrasted to white grapefruit juice in Florida and California.

The Texas Ruby Red grapefruit (*Citrus paradisi*), the major commercial citrus produced in the Lower Rio Grande Valley of Texas, poses a problem for processors since, as the fruit advance in maturity, their color fades from pink to a nondescript pinkish-brown or off-yellow. This problem was studied in detail by Lime et al. (1954, 1956, 1959), who found that adding back pulp pigment to juice would improve the color.

The Star Ruby (*Citrus paradisi Macfad*), developed by Hensz (1971) at the Texas A & I University Citrus Center, Weslaco, TX, is a seedless, dark-red-fleshed grapefruit, originating from Hudson grapefruit seed irradiated at Brookhaven National Laboratory, Long Island, NY. The deep color of the Star Ruby suggests that the juice might be blended with that of Ruby Red grapefruit such that the canned juices produced over the entire processing season and the reconstituted products would be uniform in color and of an attractive degree of pinkness. This study, a part of a larger investigation, was initiated to ascertain the differences of lycopene and carotene contents in these two grapefruit varieties with advancing maturity as well as to determine the color changes occurring in pure juices and juice blends.

## MATERIALS AND METHODS

Field run fruit of both Ruby Red and Star Ruby varieties were obtained over three harvest seasons by arrangement with the Texas A & I University Citrus Center at Weslaco, TX. Samples were taken early in the season (first or second week in December), in midseason (about the last week in January), and late in the season (about the middle or latter part of March). The fruit were washed on a set of brush rolls, and the juice was extracted in an FMC Model 091B in-line Test Extractor fitted with 0.735-mm screens. The pure juices of the two varieties and blends containing 10, 20, and 30% Star Ruby juice were canned hot in 6-oz cans. In mid- and late-season packs, a 40% blend was added.

Pigment was analyzed by method B of the procedure of Lime et al. (1957). Initially, a B and L Spectronic 20 spectrophotometer with a 0.5 in. (1.27 cm) square cuvette was used; and subsequently, in the 1976–1977 season, a Carey 15 instrument with a 1-cm cell was used. Color was determined on a Gardner color difference meter with an LR-1 standard. Values for *Rd*, *a*, and *b* were determined and the *a*/*b* ratio calculated.

## RESULTS AND DISCUSSION

Table I shows that the color of both grapefruit varieties tended to fade with advancing maturity, although both carotene and lycopene contents as well as the resulting color varied somewhat. Both spectrophotometers gave comparable results; but to adhere more closely to the original procedure of Lime et al. (1957), we changed to the 1-cm Carey cell. In the 1976–1977 season, climate may have had some effect on juice color. Rainfall was almost

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