

# Influence of Pre-drying treatments on Quality and Safety of Sun-dried Tomatoes. Part II. Effects of Storage on Nutritional and Sensory Quality of Sun-dried Tomatoes Pretreated with Sulfur, Sodium Metabisulfite, or Salt

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**ABSTRACT:** Pre-drying treatments have been found to improve the quality of stored sun-dried tomatoes. Based on previous investigation (Part I), 5 specific pretreatments were chosen for effects on nutritional value, sensory quality, and safety before and after 3 mo of storage (25 °C and 30% to 34% relative humidity). These pretreatments included (1) direct gas sulfuring with 2.3 kg (5 lb) SO<sub>2</sub>; (2) with 3.6 kg (8 lb) SO<sub>2</sub>; (3) dipping in 10% salt for 5 min; (4) 8% sodium metabisulfite for 5 min; and (5) 8% sodium metabisulfite and 10% salt for 5 min. The use of SO<sub>2</sub> improved color, rehydration ratio, and minimized the loss of ascorbic acid and lycopene. Sodium metabisulfite dipped tomatoes had better rehydration ratio and color than gas sulfured sun-dried tomatoes. Untrained consumers ranked gas sulfured tomatoes higher than sun-dried tomatoes produced by dipping in either sodium metabisulfite alone or sodium metabisulfite plus salt.

**Keywords:** tomato, sun-drying, dehydration, storage, nutrients, sensory

## Introduction

The United States produced 11.6 million metric tons of processing tomatoes, worth \$913 million, from 350,000 acres in 1999, and a slightly lower quantity (17% decrease) worth \$663 million, from 290,000 acres in 2000 (Anonymous 2001). Like other agricultural products, tomatoes are perishable and must be either consumed rapidly or preserved for later consumption. Because not all fresh tomatoes can be consumed at the time of harvest, preservation provides a larger market, allowing consumers to buy the product on a year-round basis.

Sun-drying is one of the most economical methods of food preservation. In developing countries, one of the main purposes for sun-drying tomatoes is reduction of postharvest losses (Olorunda and others 1990), whereas in developed countries, sun-dried tomatoes are considered a "gourmet" ingredient (Sloan 1999). More recently, sun-dried tomatoes have moved from the specialty food aisle to the popular produce section (CSD 1997). Today, sun-dried tomatoes have gained great acceptance in the food service segment and in the food industry as an ingredient. Growing consumer interest in health and convenience contributes to the increasing demand for consistently high quality products. However, the sun-drying industry currently faces difficulties consistently producing good quality dried tomatoes.

Tomatoes are nutritionally recognized for their vitamin C (ascorbic acid) content, with an average tomato supplying about 40% of the adult United States Recommended Daily Allowance (RDA) of 60

mg (Gould 1983). Ascorbic acid is sensitive to conditions used during drying because it is water soluble, temperature sensitive, and easily oxidized (Labuza 1973). Kareem and others (1978) reported considerable decreases in ascorbic acid content of sun-dried tomatoes; however, higher ascorbic acid concentrations were observed in sulfur dipped sun-dried tomatoes. Ascorbic acid retention appears to be affected by length of storage, temperature, and initial nutrient concentration (Gould 1983). Culpepper and others (1948) reported that after drying and storage at 10 °C for 7 mo, the retention of ascorbic acid averaged 32.8% of the original content for gas sulfured air-dried tomatoes compared with 18.1% for unsulfured air-dried tomatoes.

Lycopene is the most abundant carotenoid in tomatoes and represents about 83% of the total pigments present (Gould 1992). Tomatoes and tomato products are the major source of this phytonutrient, which has received particular interest due to its antioxidant properties. Lycopene can be considered to be an important nutrient because it appears to act as a cancer-preventive agent (Shi and others 1999). Processing and storage conditions, including high temperature, light and oxygen exposure, may cause lycopene degradation and thereby affect the attractive color and nutritive value of final products (Shi and others 1999; Shi 2000).

The most common additive used in the sun-drying industry is sulfur dioxide. Sulfur may be used as an antioxidant to prevent degradation of ascorbic acid and lycopene after sun-drying and storage. Very few studies on ascorbic acid degradation and no reported studies on lycopene degradation have been undertaken for exclusively sun-dried tomatoes (Kareem and others 1978). Salt may also be used, but preliminary studies (refer to Part I of this study) (Gupta and others 1984; Tripathi and others 1989) did not show it to be as effective as sulfur dioxide. However, when free from much iron and copper

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**Table 1—Experimental design for studies on effects of pre-drying treatments on sun-dried tomato quality and safety**

Trial dates:	9/11/01 to 9/19/01
Evaluation:	moisture, color, mold, yeast, lycopene, ascorbic acid, sensory evaluation
Samples analyzed after drying; all samples after 3 mo storage.	
Pre-drying treatments	Specific conditions
1. Sulfuring	2.3 kg (5 lb) SO <sub>2</sub>
2. Sulfuring	3.6 kg (8 lb) SO <sub>2</sub>
3. Salt dipping	10% salt, 5 min at 25 °C
4. Sodium metabisulfite dipping	8% Na <sub>2</sub> S <sub>2</sub> O <sub>5</sub> , 5 min at 25 °C
5. Salt + sodium metabisulfite	10% salt + 8% Na <sub>2</sub> S <sub>2</sub> O <sub>5</sub> , 5 min at dipping 25 °C

impurities, salt has definite antioxidant effects of its own, and it enhances the inhibition of oxidation by other antioxidants such as sulfites (Brenndorfer and others 1987). For this reason, one of the pretreatments for sun-dried tomatoes evaluated in this study was a mixture of salt and sodium metabisulfite in a dip solution.

In Part I of this study (Latapi and Barrett, forthcoming), the effects of pre-drying treatments such as steam and boiling brine blanching, and dipping in either salt or sodium metabisulfite, were investigated. Based on the results obtained in Part I, the study described in Part II focuses on 5 pretreatments determined to be most effective at maintaining quality and safety. The storage studies carried out are detailed in Table 1.

The objective of this study was to evaluate the effects of pretreatments used before sun-drying on various quality, safety, and nutritional parameters of tomatoes before and after 3 mo storage at 25 °C. These parameters include final moisture content, color, rehydration ratio, sulfur dioxide content and/or salt content, ascorbic acid, and lycopene content.

## Materials and Methods

### Raw materials and pre-drying treatments

Approximately 75 kg of ripe Halley 3155 tomatoes (Orsetti Seed Co., Hollister, Calif., U.S.A.) were obtained from the Campbell Soup Supply Co. (Dixon, Calif., U.S.A.), transported to the UC Davis Food Processing Laboratory and prepared as described previously (Latapi and Barrett, forthcoming). The 75-kg batch was divided randomly into 5 groups of 15 kg to which the following pre-drying treatments were applied:

#### Direct gas sulfuring

Two groups of 15 kg of tomato halves were separated and sulfur-treated by submitting the 1st group to 2.3 kg (5 lb) and the 2nd group to 3.6 kg (8 lb) of sulfur dioxide gas, provided by compressed sulfur dioxide in a cylinder. Each group was spread in a single layer on 61- × 122-cm wooden trays (approximately 120 tomato halves per tray) and weighed. Then the trays from the 1st group were stacked in a 1.7 m<sup>3</sup> wooden box. The box was closed tightly and covered with plastic to minimize leakage. Sulfur dioxide gas (2.3 kg or 5 lb) was injected through a tube extending into the box. The gas cylinder was mounted on a scale so the amount of gas injected could be accurately determined. The trays were kept in the sealed box for 12 h. The 2nd group was sulfured by the same method using 3.6 kg (8 lb) of sulfur dioxide gas.

#### Salt and sodium metabisulfite dipping

The 3 remaining groups of 15 kg of tomato halves were separated and dipped into the following aqueous solutions at 25 °C for 5 min:

**Table 2—Codes used for each pretreatment applied before sun-drying tomatoes**

Pretreatment	Code
Direct gas sulfured with 2.3 kg (5 lb)	SO <sub>2</sub> -2.3
Direct gas sulfured with 3.6 kg (8 lb)	SO <sub>2</sub> -3.6
Dipped in 10% salt	10% NaCl
Dipped in 8% sodium metabisulfite	8% Na <sub>2</sub> S <sub>2</sub> O <sub>5</sub>
Dipped in 8% sodium metabisulfite and 10% salt	8% Na <sub>2</sub> S <sub>2</sub> O <sub>5</sub> + 10% NaCl

(1) 10% (w/v) salt solution, (2) 8% (w/v) sodium metabisulfite solution, and (3) 10% (w/v) salt and 8% (w/v) sodium metabisulfite solution.

The weight ratio of tomato to dipping solution was 1:3 for all dipping experiments. Tomatoes were mixed continuously during dipping. After dipping, tomato halves were drained for 2 min, spread in a single layer on 61- × 122-cm wooden trays, and weighed. Refer to Table 2 for each pretreatment code used in the text.

### Sun-drying

Because only 1 sulfur box was available, it was necessary to do the SO<sub>2</sub>-3.6 kg pretreatment 1 d after the SO<sub>2</sub>-2.3 kg pretreatment. Trays of tomatoes pretreated with SO<sub>2</sub>-2.3, 10% NaCl, 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub>, and 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub> + 10% NaCl were placed on the roof of the Food Processing Laboratory at the same time and exposed to direct sunlight for 9 d (September 11-19, 2001). Tomatoes pretreated with SO<sub>2</sub>-3.6 kg were placed with the rest of the trays to dry on September 12 (1 d later). All pretreated tomatoes were considered dried when their moisture content was reduced from about 94% to 14% to 15% (wet basis). Outside temperature and relative humidity were monitored with an Omega data logger (Omega Technologies Co., Model OM-550, Stamford, Conn., U.S.A.) and compared with the weather data retrieved from the web site of the Univ. of California Statewide Integrated Pest Management Project (UC IPM 2001). This information is given for each drying d in Table 3.

Dried tomatoes used for sensory evaluation were stored in a conventional refrigerator at about 8 °C for 30 d; all other samples were packed into sealed polyethylene bags and stored at -20 °C. After drying, 6 sets of representative samples were taken randomly from each of the 5 treated groups. One set was analyzed for moisture content (10 g), a 2nd set for rehydration ratio and color (40 g), a 3rd for mold and yeast count (50 g), a 4th for ascorbic acid and lycopene content (10 g), a 5th for sensory evaluation (60 g), and a 6th for storage at 25 °C and 30% to 34% relative humidity for 3 mo (110 g). Extra sets of samples were taken for sulfur dioxide (50 g) and salt content (40 g) from the batches that required such analyses. One average tomato half weighed approximately 3.5 g.

### Storage

Tomato samples of approximately 110 g from each of the 5 pre-drying treatments were stored in sealed polyethylene bags (17.8 cm × 20.3 cm and 2.7-mil thickness) at 25 °C and 30% to 34% relative humidity for 3 mo. After 3 mo, the same analyses that were carried out before storage were made except for sensory evaluation.

### Analytical methods

Triplicate determinations were carried out for moisture, lycopene, and ascorbic acid content. Moisture content (% moisture w/w) was determined using the vacuum oven method as per AOAC (1984). Lycopene (mg/g dry weight) was determined by a spectrophotometric method based on that of Barrett and Anthon (2000).

**Table 3—Weather conditions during the drying period used for sun-drying tomatoes<sup>a</sup>**

Date (mm-dd-yy)	Temperature <sup>b</sup> (°C)		Relative humidity <sup>c</sup>		Solar radiation <sup>e</sup> (LY)	Wind speed <sup>d</sup>		Degree-days (heat units)
	Max	Min	Max	Min		Direction	Miles/h	
09-11-01	28.9	13.9	83.7	33.9	180	NW	2	17.00
09-12-01	27.2	11.7	92.7	40.1	252	S	3	15.05
09-13-01	30.0	10.6	90.2	31.9	251	S	1	15.90
09-14-01	33.9	13.9	78.2	28.3	247	S	2	19.50
09-15-01	31.1	12.2	88.1	26	248	S	2	17.25
09-16-01	27.2	12.2	94.1	43.1	247	S	2	15.30
09-17-01	30.0	10.0	87.9	35.5	244	S	2	15.60
09-18-01	30.0	11.7	86.6	35.1	233	S	2	16.45
09-19-01	31.7	11.1	85.6	31.9	231	S	2	17.00
								Accumulated degree-days 149.05

<sup>a</sup>Data from California Weather Databases. Univ. of California. Statewide Integrated Pest Management Project. All data were retrieved from station Davis. A (CIMIS nr 6, Davis).

<sup>b</sup>Air temperature: daily max/min measured at 1.5 m.

<sup>c</sup>Humidity: daily max/min relative humidity measured at 1.5 m.

<sup>d</sup>Wind speed and direction: daily average measured at 2 m.

<sup>e</sup>Solar radiation: daily global radiation measured by Licor pyranometer at 2 m.

<sup>f</sup>Accumulated degree-days is the sum of all the degree-days for each replicate or drying period.

Two grams of cut, dried sample were homogenized with distilled water using a Polytron (Brinkmann Instruments Inc., Model PCU11, Westbury, N.Y., U.S.A.). One hundred milliliters of tomato pulp was pipetted into a screw-capped tube, then 10 mL of 4:3 (v/v) ethanol: hexane was added and the mixture was incubated for 1 h. One milliliter of water was added to each sample, which was left to stand for 10 min. A sample of hexane layer was removed and read at OD 503 versus hexane in a spectrophotometer.

Ascorbic acid (mg/g dry weight) was determined using a spectrophotometric method based on that of Tsumura (Tsumura and others 1993). One gram of cut, dried sample was homogenized with distilled water using a Polytron (Brinkmann Instruments Inc., Model PCU11). The paste was centrifuged and the supernatant removed for analysis. In a 3-mL cuvette, 2.5 mL of 0.1 M sodium phosphate (pH 6.5), 100 mL of sample, 400 mL of water, and 5 mL of 1.0 mg/mL horseradish peroxidase (Sigma Type II, St. Louis, Mo., U.S.A.) were mixed. The sample was read at OD 265 in a spectrophotometer and 50 mM hydrogen peroxide was added. The sample was read again until it reached an absorbance value of OD 265 again. The difference between the beginning and ending absorbance at OD 265 was used to calculate ascorbic acid content.

The color of the sun-dried tomatoes was measured using a Minolta colorimeter, Model CR-200 (Ramsey, N.J., U.S.A.). Thirty replicates were carried out per 40 g of each sample and color was reported as hue angle. The optimum hue angle for sun-dried tomatoes was considered the value nearest to that hue angle (range, 24 to 28) of a fresh tomato. Mold was determined as previously described (Latapi and Barrett, forthcoming). Analyses of rehydration ratio, sulfur dioxide, and salt content were carried out in duplicate (Latapi and Barrett, forthcoming).

### Sensory evaluation

Sun-dried tomatoes pretreated with SO<sub>2</sub>-3.6 kg, 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub>, and 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub> + 10% salt were evaluated for sensory qualities after 30 d of storage at 8 °C. The direct gas sulfured sun-dried tomatoes with the highest sulfur dioxide, SO<sub>2</sub>-3.6 kg, were chosen for the sensory evaluation. The 10% NaCl treated sun-dried tomatoes were discarded because immediately after sun-drying, yeast was detected at a level of 13 × 10<sup>5</sup> colony-forming units (CFU)/g, exceeding the allowable limits (10<sup>3</sup>/g); furthermore, these tomatoes exhibited off-odors with physical signs of spoilage.

Sun-dried tomatoes were rehydrated 24 h before tasting using

the method for rehydration ratio described in the "Materials and Methods" section. Three replicate samples (1 sun-dried tomato half per replicate) of the 3 rehydrated sun-dried tomato samples being evaluated (SO<sub>2</sub>-3.6 kg, 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub>, and 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub> + 10% salt) were presented at random to 200 untrained consumers (114 females and 88 males). Samples were evaluated for liking on the 9 point Hedonic scale, where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Data were analyzed by Analysis of Variance and the Fisher's Least Significance Difference Test was used to compare differences among means at the 0.05 level. Microsoft Excel (2000) for Windows computer software was used for this analysis.

### Results and Discussion

After 8 d of sun-drying, the moisture content of tomatoes was reduced from an initial level of about 94% to a final value of 14% to 15% (wet basis). After 3 mo of storage at 25 °C and 30% to 34% relative humidity, moisture content increased slightly to about 16% to 17% for all samples. No yeast growth was detected before or after storage on SO<sub>2</sub>-2.3, SO<sub>2</sub>-3.6, 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub>, and 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub> + 10% NaCl samples. The 10% NaCl sun-dried tomatoes had a yeast count of 13 × 10<sup>5</sup> CFU/g before storage, exceeding allowable limits (10<sup>3</sup>/g) set by the Intl. Commission for Microbiological Specifications for Foods (ICMSF); they also presented off-odors with physical signs of spoilage. After 3 mo of storage, yeast counts in tomatoes pretreated with 10% NaCl decreased to <10 CFU/g. Apparently the viable yeast that were initially counted did not survive storage conditions.

All sun-dried tomatoes had less than 10 CFU/g mold before storage (Figure 1). This could be accounted for by the low moisture content of all samples. However, after 3 mo of storage, mold growth was detected in the 10% NaCl, 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub>, and 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub> + 10% NaCl samples at 60, 20, and 30 CFU/g, respectively. These mold count increases were still below the limits allowed by the ICMSF (10<sup>4</sup>/g), however, and may possibly be explained by contamination during the dipping pretreatment.

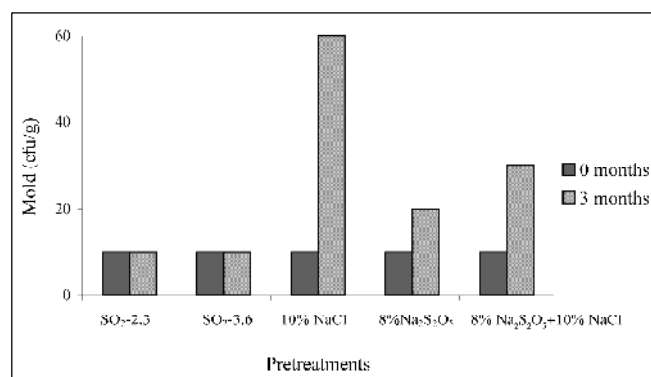
Figure 2 illustrates rehydration ratios in the sun-dried tomatoes before and after 3 mo storage for the 5 different pretreatments applied. The 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub> had the highest rehydration ratio both before (3.51) and after storage (3.40), followed by 8% Na<sub>2</sub>S<sub>2</sub>O<sub>5</sub> + 10% NaCl with 3.0 before storage and 2.9 after storage. The high rehydration ratios of the latter pretreated tomatoes infer greater prod-

uct hydration, less damage to tissue during drying and storage, and thus higher quality. This supports studies reported by Tripathi and Nirankar (1989) and Olorunda and others (1990), who showed that the use of metabisulfite solutions as a pretreatment before drying tomatoes improves rehydration. Both  $\text{SO}_2$ -2.3 kg and  $\text{SO}_2$ -3.6 kg had the same rehydration ratio (2.8) before and after storage. Mazza (1983) and Jayaraman and others (1990) also reported that pretreatments, such as salts of sulfite, increase rehydration capacity of dried products. Tomatoes pretreated with 10% NaCl had the lowest rehydration ratio of all samples, both before (2.51) and after (2.46) storage. This could be due to an accumulation of salt crystals on the product, decreasing water adsorption during hydration.

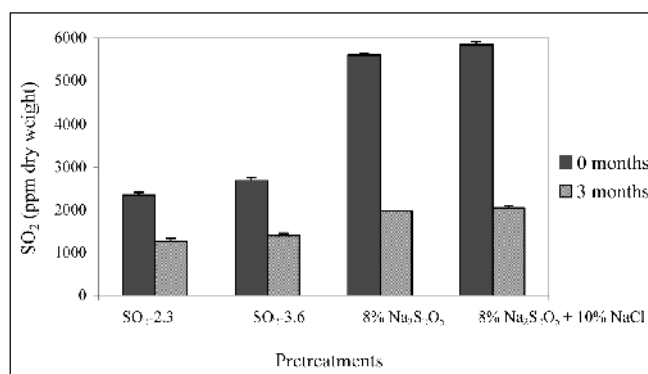
Before storage, sun-dried tomatoes pretreated with 8%  $\text{Na}_2\text{S}_2\text{O}_5$  and 8%  $\text{Na}_2\text{S}_2\text{O}_5 + 10\%$  NaCl had higher levels of sulfur dioxide (5600 and 5833 ppm, respectively) than those pretreated with  $\text{SO}_2$ -2.3 kg and  $\text{SO}_2$ -3.6 kg (2346 and 2681 ppm, respectively) (Figure 3). After 3 mo of storage, the sodium metabisulfite-treated tomatoes lost up to about 65% of their initial sulfur dioxide content, whereas those treated with  $\text{SO}_2$  lost only about 48%. Babalyk and others (1997) obtained similar results. They showed that during storage at 30 °C, sulfur dioxide degrades at a higher rate in tomatoes with a higher initial content than in those with smaller concentrations. Davis and others (1973) reported that dried apricots with a greater initial sulfur content stored at 25 °C for 48 wk exhibited higher loss rates than those with a lower initial content. According to their

study, 25% of the sulfur in these apricots was in free form, whereas only 17% was free in fruit containing less initial sulfur. This indicates that most of the sulfur in sun-dried tomatoes with a high initial content was in free form, which explains the increased rate of loss compared with dried tomatoes with lower initial sulfur content.

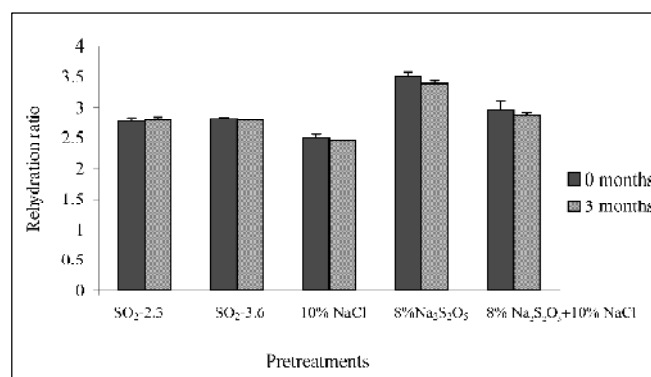
The lower the hue angle, the redder the sample and the more desirable the color. Hue angles increased for all treated sun-dried tomatoes after 3 mo of storage (Figure 4). The greatest increase was observed in those treated with 10% NaCl, followed by both  $\text{SO}_2$ -2.3 kg and  $\text{SO}_2$ -3.6 kg, and finally by 8%  $\text{Na}_2\text{S}_2\text{O}_5$  and 8%  $\text{Na}_2\text{S}_2\text{O}_5 + 10\%$  NaCl. Sun-dried tomatoes treated with sulfur (either by gas or dipping) retained more red color than unsulfured tomatoes (10% NaCl). Sulfur dioxide inhibits discoloration by blocking compounds with a reactive carbonyl group (Maillard reaction; nonenzymatic browning) or by inhibiting oxidation of phenols by phenol oxidase enzymes (enzymatic browning) (Belitz and Grosch 1999). After 3 mo of storage, sun-dried tomatoes pretreated with sodium metabisulfite (8%  $\text{Na}_2\text{S}_2\text{O}_5$  and 8%  $\text{Na}_2\text{S}_2\text{O}_5 + 10\%$  NaCl) had lower hue angles (33.27 and 33.56 hue°, respectively) and thus more intense red color than direct gas sulfured tomatoes  $\text{SO}_2$ -2.3 kg and  $\text{SO}_2$ -3.6 kg (35.02 and 34.78 hue°, respectively). Although it has been reported that salt reduces enzymatic browning and discoloration (Brenndorfer and others 1987), in this study, both before and after storage, 10% NaCl dipped sun-dried tomatoes had higher hue angles and appeared a darker brown color than the sulfured product.



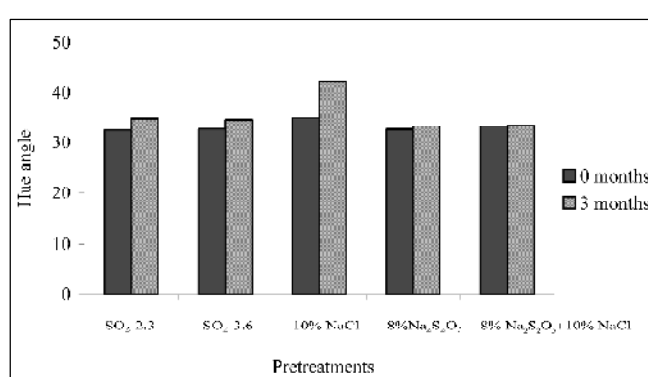
**Figure 1—Changes in mold count (colony-forming units [CFU]/g) of sun-dried tomatoes before and after 3 mo of storage at 25 °C and 30% to 34% relative humidity**



**Figure 3—Changes in sulfur dioxide content (dry weight) of sun-dried tomatoes before and after 3 mo of storage at 25 °C and 30% to 34% relative humidity. Means are based on duplicate values. Vertical bars represent standard deviation.**



**Figure 2—Changes in rehydration ratio of sun-dried tomatoes before and after 3 mo of storage at 25 °C and 30% to 34% relative humidity. Means are based on duplicate values. Vertical bars represent standard deviation.**



**Figure 4—Changes in hue angle values of sun-dried tomatoes with different pretreatments before and after 3 mo of storage at 25 °C and 30% to 34% relative humidity. Results are average of 30 replicates.**

Ascorbic acid content in fresh tomatoes was 3.37 mg/g dry weight. During sun-drying, all tomatoes lost ascorbic acid (Figure 5), supporting previous studies of ascorbic acid retention. Gupta and Nirankar (1984) and Gallali and others (2000) discovered that sun-drying results in appreciable ascorbic acid losses, whereas Ojime-lukwe (1994) reported a reduction of up to 54%. In this study, the greatest ascorbic acid loss occurred in the 10% NaCl dipped tomatoes with losses up to about 97.3%. The type of sulfuring process seems to have an effect on ascorbic acid loss because tomatoes pretreated with 8%  $\text{Na}_2\text{S}_2\text{O}_5$  and 8%  $\text{Na}_2\text{S}_2\text{O}_5$  + 10% NaCl lost up to about 94% of their initial ascorbic acid content, whereas for those pretreated with  $\text{SO}_2$ -2.3 kg and  $\text{SO}_2$ -3.6 kg, lost only about 82% of the initial content.

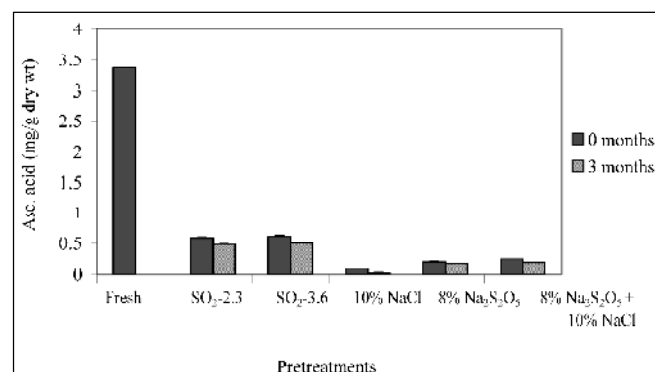
It has been reported that fruit products treated with sulfur dioxide have reduced ascorbic losses during processing, as well as during storage (Cruess 1958; Quast and Karel 1972; Bolin and Stafford 1974). Results from this study support this observation; sulfur dioxide not only reduced the ascorbic acid loss rate during processing, but it also gave added protection during storage. The highest losses (76%) of ascorbic acid after storage were observed again in the 10% NaCl sun-dried tomatoes, whereas all tomatoes sulfured either by gas or dipping lost less than 21%. Using sulfur dioxide as

a preservative in sun-dried tomatoes can minimize the loss of ascorbic acid both during processing and storage.

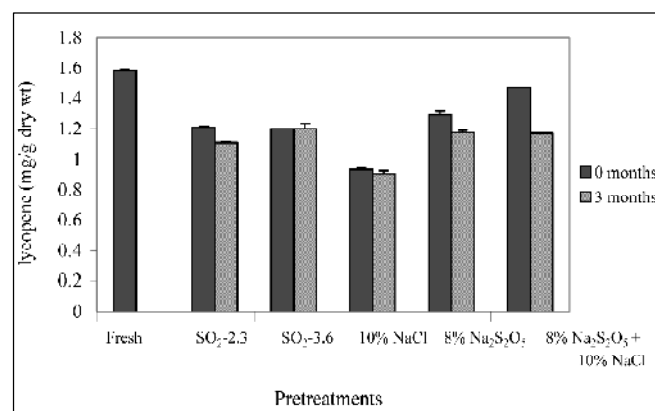
Sulfur dioxide gas and sodium metabisulfite pretreatments reduced the rate of lycopene degradation during both sun-drying and storage of sun-dried tomatoes compared with the 10% NaCl pretreatment (Figure 6). The lycopene content in fresh tomatoes was 1.58 mg/g dry weight. After sun-drying 10% NaCl pretreated tomatoes showed a reduction in lycopene content of 41% to 0.93 mg/g dry weight. This loss is higher than that reported by Gupta and others (1982) who observed losses of less than 17% in tomatoes sun-dried without any pretreatment. The percentage loss was also higher than that reported by Zanoni and others (1999) for mechanical drying. This study showed that no significant loss of lycopene occurred when drying in a pilot-plant cabinet air dryer at 80 °C. In contrast, drying at 110 °C resulted in a significant loss (12% maximum). One possible reason for higher lycopene degradation with sun-drying is that tomatoes are exposed solar radiation for a longer period of time than with heated air-drying. All sulfured sun-dried tomatoes lost less than 25% of their initial lycopene content. The highest lycopene content after sun-drying was detected in the 8%  $\text{Na}_2\text{S}_2\text{O}_5$  (1.28 mg/g dry weight) and 8%  $\text{Na}_2\text{S}_2\text{O}_5$  + 10% NaCl (1.47 mg/g dry weight) tomatoes. Tripathi and others (1988) reported no significant losses of lycopene in air-dried tomatoes blanched in 2.5% brine for 60 s and dipped 2 min in sulfited starch. Our results were also in agreement with Bolin and Stafford (1974) study of carotenoid retention in apricots and that of Baloch (1987) on carrots. Both reported that the use of sulfur is effective in retarding carotenoid degradation. The main cause of damage to lycopene during food processing and storage is oxidation; thus, sulfur dioxide functions as an effective antioxidant preventing lycopene oxidation. The low oxygen content, low water activity, and low moisture content of stored sun-dried tomatoes also prevented the degradation of lycopene (Shi 2000).

Losses in salt content, which could have occurred during handling and packaging of stored sun-dried tomatoes, were observed in both 10% NaCl and 8%  $\text{Na}_2\text{S}_2\text{O}_5$  + 10% NaCl after storage (Figure 7). Some of these losses could also be attributed to the antioxidant effect of salt and its ability to inhibit oxidation and oxidizing enzymes (Brenndorfer and others 1987).

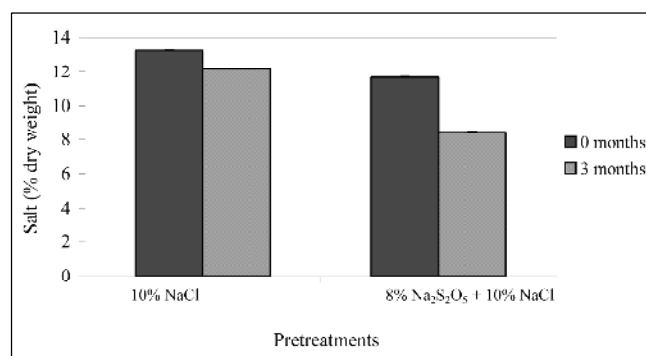
Mean liking scores from the sensory evaluation of indicated that the sun-dried tomatoes pretreated with 3.6 kg of  $\text{SO}_2$  had the highest mean score ( $6.2 \pm 1.9$ ) and were liked significantly more ( $P < 0.05$ ) than the other 2 pretreated tomatoes (8%  $\text{Na}_2\text{S}_2\text{O}_5$  and 8%  $\text{Na}_2\text{S}_2\text{O}_5$



**Figure 5—Changes in ascorbic acid content (mg/g dry weight) of sun-dried tomatoes before and after 3 mo of storage at 25 °C and 30% to 34% relative humidity. Means are based on triplicate values. Vertical bars represent standard deviation.**



**Figure 6—Changes in lycopene content (mg/g dry weight) of sun-dried tomatoes before and after 3 mo of storage at 25 °C and 30% to 34% relative humidity. Means are based on triplicate values. Vertical bars represent standard deviation.**



**Figure 7—Changes in percent salt content (dry weight) of sun-dried tomatoes before and after 3 mo of storage at 25 °C and 30% to 34% relative humidity. Means are based on duplicate values. Vertical bars represent standard deviation.**

+ 10% NaCl). Consumers rated the  $\text{SO}_2$ -3.6 kg treated sun-dried tomatoes at about "like slightly" on the 9-point Hedonic Scale. There was no significant difference ( $P > 0.05$ ) of liking between the 8%  $\text{Na}_2\text{S}_2\text{O}_5$  ( $5.7 \pm 1.8$ ) and 8%  $\text{Na}_2\text{S}_2\text{O}_5$  + 10% NaCl ( $5.5 \pm 2.1$ ) sun-dried tomatoes, and their scores were close to the "like slightly" level on the 9-point Hedonic scale.

One possible reason that panelists liked the  $\text{SO}_2$ -8 samples most could be their lower sulfur dioxide content; initially they contained about fifty percent less than the 8%  $\text{Na}_2\text{S}_2\text{O}_5$  and 8%  $\text{Na}_2\text{S}_2\text{O}_5$  + 10% NaCl samples. Panelists may have been able to detect a more sulfurous flavor in the sodium metabisulfite treated samples. Further studies of direct gas sulfured vs. sulfur dipped tomatoes, using the same sulfur dioxide quantities, would be necessary to conclude if sulfuring method has an effect on the sensory qualities of sun-dried tomatoes.

### Conclusions

Overall, the 10% NaCl pretreated sun-dried tomatoes had the poorest quality of all pretreated tomatoes. The 8%  $\text{Na}_2\text{S}_2\text{O}_5$  and 8%  $\text{Na}_2\text{S}_2\text{O}_5$  + 10% NaCl sun-dried tomatoes had the best rehydration ratio and color values. However, the  $\text{SO}_2$ -2.3 kg and  $\text{SO}_2$ -3.6 kg tomatoes had better ascorbic acid retention, and the latter was most liked in the sensory evaluation. Further studies, comparing both sulfuring methods (direct gas versus sodium metabisulfite dip) and using the same quantities of sulfur dioxide are required to determine precise effects on the different quality parameters measured in this study.

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