Table 5. Solar drying data for sliced mangos (2 consecutive days) and mushrooms (3 consecutive days) in the strip-frame dryer.

Sample	Initial solids %	Loading rate lbs/ft^2	Drying time hrs	Heat flux^z cal/cm^2	Final solids %	H_2O/solids
Mango						
cv. Tommy Atkins	14.2	1.0	7	428	54.7	0.83
1/4 in. slices			6	400	88.2	0.13
Mushrooms	3.8	2.0	4.5	97	5.4	17.5
3/8 in. slices			7.2	389	16.4	5.1
			6	292	86.8	0.15

^{z}Measured on a horizontal Eppley pyranometer.

plywood model showed, as would be expected, that final % solids decreased as loading was increased. Since the plywood and the strip frame models have the same reflective area, these drying data indicate air circulation may be a predominant influence. Results from the FSEC dryer (with an electric fan for forced air circulation) appeared to verify this. Peaches dried in the FSEC dryer required less time and radiant energy than those dried in the strip frame model at the same loading rate. Except for the lowest loading rate [1 lb/ft^2 (4.93 kg/m^2)] the advantage in the FSEC dryer is achieved at the cost of additional energy for the forced-air circulation system. As expected, conventional hot-air drying required less drying time than did either solar dryer. All 3 solar dryers produced dried peaches with commercially satisfactory solids contents.

Preliminary results of drying sliced mangos and mushrooms on the strip frame model are shown in Table 5. At a loading rate of 1.0 lb/ft^2 (4.9 kg/m^2) mango slices dried to 54.7% solids in 7 hr. The H_2O/solids ratio was reduced from 6.04 to 0.83. The second solar period (6 hrs) was longer than necessary, for mangos should be dried to the same final solids contents as peaches (72-75%). Thus, this sample was somewhat overdried. These results indicate mangos could be satisfactorily dried on this model dryer in less than two solar days. Mushrooms loaded at 2.0 lb/ft^2 (9.8 kg/m^2) dried to an acceptable 87% solids in 3 solar periods (17.7 solar hrs). The H_2O/solids ratio during the first period was reduced from 19.8 to 7.5, while in the second period it was reduced to 5.1. Although no formalized sensory evaluations were carried out, informal tests have indicated all the products dried with these low-cost small-scale solar models were acceptable.

In conclusion, a low-cost, easily constructed solar home food dryer has been developed; it uses a unique parabolic reflector formed from strings and aluminum foil to augment solar radiation and shorten drying time. It produced dried fruit and vegetables comparable with those from an elaborate, costly solar dryer or from a conventional hot-air dryer.

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STORAGE STABILITY OF SOLAR DRIED AND HOT-AIR DRIED GREEN PEPPERS

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Abstract. **During storage, changes in flavor and color of dried green peppers were not as great as changes in vitamin C content. Solar dried or hot-air dried samples, pretreated with different concentrations of sodium bisulfite solutions were stored at 35°F (2°C), 70°F (21°C), or 85°F (30°C). Retention of vitamin C, flavor, color and SO_2 were periodically determined over 12 weeks. Rapid reduction in vitamin C content tended to follow the reduction of SO_2 content at 70°F (21°C) and 85°F (30°C).**

In the U. S., green peppers (*Capsieum Amuum* L.—bell peppers) are grown on commercial farms, as well as in smaller home and farm gardens in the South. Large quantities of peppers are available for drying 2 or 3 times each year (1). Commercially, green peppers are commonly preserved by hot-air drying and the dried products may be used

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*Southern Region, U. S. Department of Agriculture, Science and Education Administration.

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for soup mixes, salads, and other vegetable dishes, Replacing conventional gas-fired, hot-air drying, with solar drying could conserve nonrenewable energy and reduce operational costs.

Research on the direct solar drying of tropical and subtropical fruits and vegetables is a continuing project at the U. S. Citrus and Subtropical Products Laboratory. As part of this program we have designed, built and tested several solar food dryers, evaluated pretreatments for sun-dried and hot-air dried fruits and vegetables, and completed tests on storage stability of solar-dried and hot-air-dried green peppers. We reported on preliminary evaluations of sulfite pretreatments for sun-dried and hot-air-dried green peppers in 1978 (2).

Green peppers are an excellent source of vitamin C, with ascorbic acid present in concentrations as high as 172 mg/100 g (3). Matthews *et al.* (4) found a significant reduction of vitamin C in fresh green peppers stored at 70°F (21°C) and 45°F (7°C), and better retention at the lower temperature (4). In another study Matthews *et al.* (5) found a 12% reduction of vitamin C in frozen green peppers stored for 8 months at 0°F (−17.8°C). In neither study was the effect of SO_2 or drying on preservation of color, flavor or vitamin C examined.

Use of sulfur dioxide, as bisulfite or a gas, is well-known and documented, and information on commercial hot-air drying of green peppers is readily available. Van Arsdel *et al.* (1) recommended levels of 1000-2500 ppm SO_2 in the final dried product for preservation of flavor and color in dried fruits and vegetables where a sulfite/bisulfite solution was used. Bolin and Stafford (6, 7) described sulfite use and applications in fruits, but little information is available on processing techniques for retaining the recommended concentrations (1000-2000 ppm) in the final dried products. We are reporting studies on SO_2 retention, color, flavor, and vitamin C retention by solar-dried and conventionally hot-air-dried green peppers during storage.

Materials and Methods

Produce and pretreatments

Green peppers (4.5 bushels; average percent solids, 6.71) obtained on two occasions (9 bushels total) from a wholesale produce outlet were held at 10°C (50°F) in their commercial carton for 24 hr before initial use. Peppers were halved, cored, and deseeded by hand; then they were sliced into 3/8-in. (9-mm) strips with an Urschel food slicer. These strips were placed in a basket (39 cm high x 18 cm diameter) of #8 mesh stainless steel screen and dipped in a solution of reagent-grade sodium sulfite (Na_2SO_3) (Mallinckrodt Chemical Company) in tap water. Four concentrations of sulfite were prepared. They were 1230 and 2475 ppm SO_2 for the two samples (#1 and #2, respectively) to be solar dried, and 3375 ppm SO_2 for the two samples (#3 and #4, respectively) to be air-dried. For dipping, the basket was immersed 5 sec and drained 1 sec. This was repeated for 3 min.

Drying

Samples #1 and #2, sliced peppers (3800 g each) were dried on stainless steel mesh trays (3-mm openings) enclosed in a glass-covered solar/hot-air dryer in a 24-hr 2 stage process described by Bryan *et al.* (8). A planar aluminum reflector provided solar radiation to the bottom of the drying area. The samples also received direct solar radiation from the top. Trays were loaded at 2.5 lb/ft^2 (12 kg/m^2) and air flow at 3.8 ft/min (1.2 m/min) was provided upward through the tray by an electric blower. Most moisture was evaporated during the day and drying was completed overnight with air heated to 140°F (60°C). Final product was about 89% solids.

Samples #3 and #4, and control samples, (7600 g, no sulfite) were dried on stainless steel mesh trays with 2 mm openings measuring 2.56 ft^2 (0.237 m^2) in a pilot-scale, recirculating air dryer (National Drying Machinery Company) with a tray loading of 1.64 lb/ft^2 (8.0 kg/m^2), were dried for 2 hr at 160°F (71°C), and then for 3 hr at 145°F (63°C). Final solids were about 90%.

Storage after drying

Control samples and samples 1-4 were sealed in a number two can and retained for comparison in flavor and color tests. Samples of each concentration (1-4) and controls were stored at 85°F (30°C), 70°F (21°C), and 35°F (2°C) until analysed during the 2nd, 3rd, 4th, 6th and 12th weeks.

Analyses

Percent solids were calculated from weight loss after blending and drying 16 hr @ 70°C, @ 10 mm Hg.

A modified direct colorimetric method was used for the determination of sulfur dioxide (SO_2), with sodium tetrachloromercurate as a stabilizing solution and acid-bleached pararosaniline hydrochloride as an indicating dye (9). Because the method is not accurate for SO_2 concentrations below 150 ppm, all such levels are reported as 150 ppm.

For measurement of ascorbic acid, 5-10 g samples of pepper were ground in 50 ml buffer for 1 min and washed with deionized water. The washed samples were titrated with standard 2,6-dichloroindophenol to a potentiometric end point. This is a modification of the AOAC method (10).

Taste evaluation

Five-gram samples were soaked in 300 ml deionized water for 30 min, drained, cooled to room temperature and served to 5 taste evaluators. Four or five panelists familiar with taste-testing procedures evaluated samples on a hedonic scale of 1-5 (1 = poor flavor, and 5 = good). Mean values of the flavor evaluation scores were used to compare results.

Color analysis

A MacBeth Examolite Model EBA 220 was used to compare experimental samples with controls stored at 35°F (2°C). At each sampling period samples were color rated as: 3 = same as the 35°F (2°C) storage control, 4 = slightly darker than control, and 5 = distinctly darker than control. All color analyses reported here were on dried samples.

Results and Discussion

Sulfite content in the final product varied with concentration of the dip solution, storage time and storage temperature. Before accurate sulfite retention values could be obtained, the relationship between dip concentrations and sulfite retained on the fresh, cut samples had to be determined. Sulfite content for each lot increased in almost direct proportion with sodium sulfite concentration, but variation between lots was observed (2).

SO_2 concentrations in solar-dried and air-dried samples stored at 85°F (30°C) (Fig. 1), 70°F (21°C) (Fig. 2) and 35°F (2°C) (Fig. 3) decreased rapidly during the first few weeks of storage. Rate of SO_2 loss varied inversely with initial dip concentration regardless of whether the fruits were solar-dried or hot-air-dried. At the end of the 12-week test period, both solar- and air-dried green peppers stored

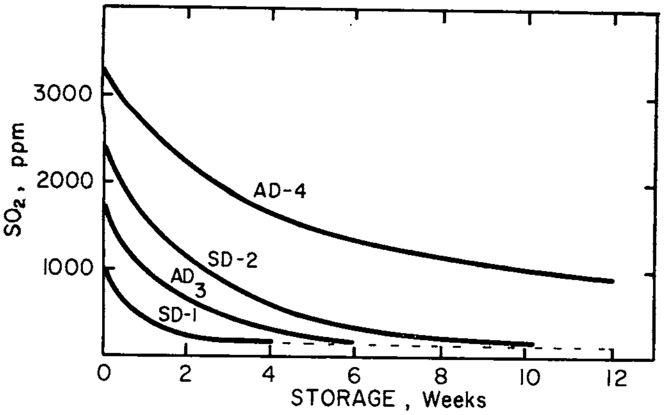

Fig. 1. 85°F Storage stability (SO_2).

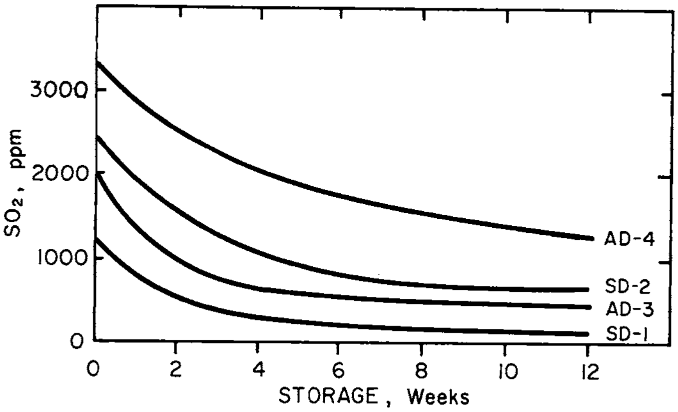

Fig. 2. 70°F Storage stability (SO_2).

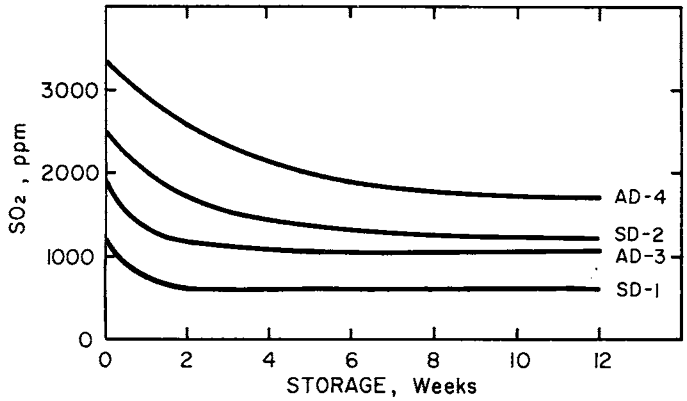

Fig. 3. 35°F Storage stability (SO_2).

at 35°F (2°C) had concentrations of 1200 and 1700 ppm SO_2 respectively, well above Van Arsdel's recommended lower level of 1000 ppm SO_2. Hot-air-dried samples stored at 70°F (21°C) for 12 weeks, (sample #4) retained 1300 ppm SO_2 (Fig. 2). The dotted line in Figure 1 indicates the lower limit of the SO_2 analysis at 150 ppm. Extracts of the dried green peppers occasionally had a perceivable cloud which neither filtration nor centrifugation would remove. Our results show that cost analyses may be warranted to determine the best combination of storage temperature and SO_2 dip concentration for an anticipated or desired average shelf-life of this product.

Samples had better stability at higher SO_2 concentrations. Figure 4 [35°F (2°C)] shows the storage stability of the combined solar dried and hot-air dried samples. Storage stability of vitamin C in the dried samples was higher at 70°F (21°C) (Fig. 5) than at 85°F (30°C) (Fig. 6). There appeared to be little differences between drying treatments (solar and hot-air) with respect to vitamin C retention. In all samples the rate of vitamin C loss at 35°F (2°C) was much lower than the rates of loss at 70°F (21°C) and 85°F (30°C). These low rates of loss, along with experimental error, made individual product analyses of the 35°F (2°C) storage samples difficult. All products from this storage

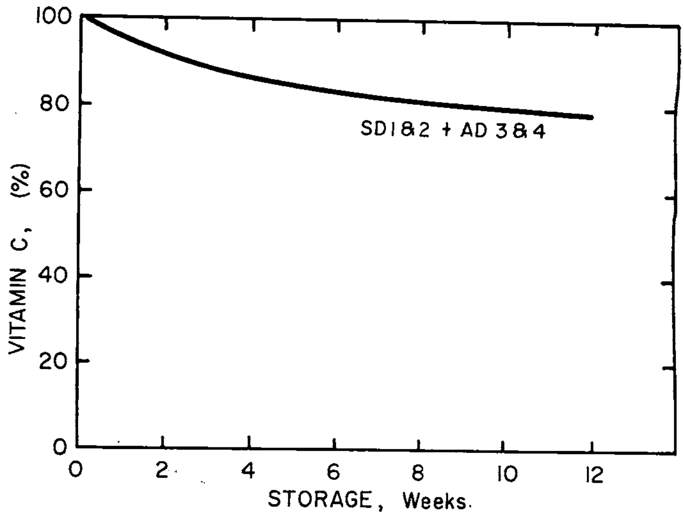

Fig. 4. Green pepper average Vitamin C storage stability 35°F.

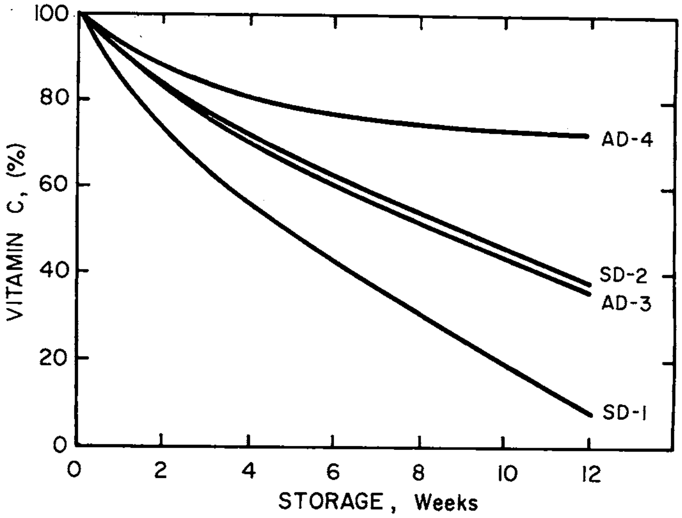

Fig. 5. Green pepper Vitamin C storage stability 70°F.

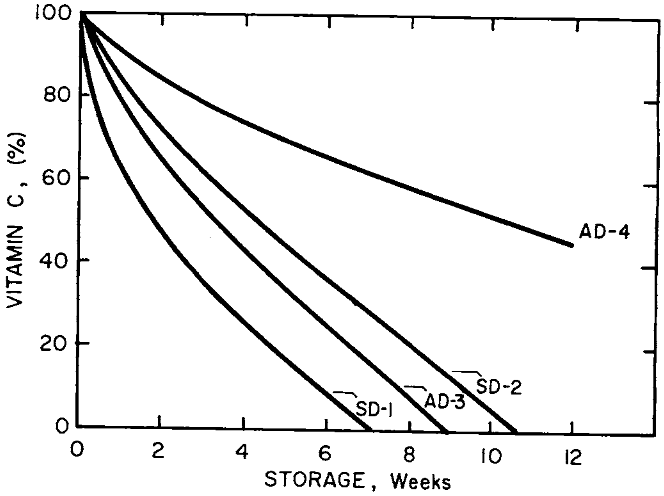

Fig. 6. Green pepper Vitamin C storage stability 85°F.

temperature ranged between 72-89% vitamin C retention through the 6th week, regardless of drying method. Vitamin C content was rapidly reduced in all samples at 70°F (21°C) (Fig. 5) and 85°F (30°C) (Fig. 6), and the loss was faster at the higher temperature. At 70°F (21°C), after about 6 weeks, there was some tendency for rates of loss to level off, or decline. However, at 85°F, loss of vitamin C continued at a high rate throughout the 12-week period. One sample, air-dried #4, consistently showed higher retention of vitamin C than dried samples 1-3. For example, Figure 6, air-dried #4 still retained about 50% of its vitamin C after 12 weeks at 85°F (30°C), while the other samples retained no vitamin C. The reason for better retention of vitamin C in air-dried #4, is unknown but might relate to the higher SO_2 retention in this sample.

Samples stored at 70°F (21°C) darkened (only slightly less) than those stored at 85°F (30°C). Hot-air-dried samples were nearer the color of the control than the solar-dried samples, which were usually darker than the controls. Most notable, however, was the color difference between solar dried #1 and air-dried #4. Solar-dried #1 was darker than the control. It was also the sample treated with the lowest SO_2 concentration (1230 ppm) and had the poorest vitamin C retention. On the other hand, air-dried sample #4 was the sample least altered in appearance by drying and storage, and it was the sample treated with the highest SO_2 concentration (3375 ppm) and had the best vitamin C retention.

Average flavor ranking during this 12-week storage study appears higher for the dried product with greater SO_2 concentrations regardless of drying method. In general, lower storage temperatures resulted in more flavorful products. These color and flavor tests on solar-dried and hot-air dried green peppers tend to confirm Van Arsdel et al's. (1) findings that sulfur dioxide will preserve the color and flavor of dried vegetables.

In summary our 12-week storage stability investigation showed a decreasing rate of SO_2 loss as storage temperature was reduced. Dried green pepper samples with higher initial concentrations of SO_2 (2475 and 3375 ppm) exhibited a lower rate of SO_2 loss than the samples with lower initial SO_2 concentrations (1230 and 2025 ppm). Storage stability of vitamin C at 85°F (30°C) and 70°F (21°C) was directly related to SO_2 concentration over 12 weeks of storage. Color and flavor scores were generally better for those samples with higher SO_2 concentrations at all temperatures. For best quality and nutrition in conventionally dried, or solar-dried products, some SO_2 treatment is beneficial. Also, although dried products are generally presumed to be relatively stable without refrigeration, color and vitamin C were retained better at lower temperatures. Generally, there did not appear to be any differences in flavor or vitamin C stability attributable to solar-drying methods.

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BIOLOGY AND CONTROL OF GEOTRICHUM CANDIDUM, THE CAUSE OF CITRUS SOUR ROT[1]

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Abstract. Geotrichum candidum **was isolated from the soil and from fruit surfaces using a selective medium of Difco potato dextrose agar containing novobiocin (100 ppm), benomyl (100 ppm) and dicloran (50 ppm).** G. candidum **was consistently recovered from soil removed from the surface of the grove floor. The organism was recovered from fruit surfaces at varying frequencies, and was often isolated from the button (calyx with disk). Surface concns of** G. candidum **were increased when fruit were dropped to the ground during picking. Two experimental materials, CGA 64251 and Panoctine, were the most active against** G. candidum **in** in vitro **tests. Both reduced the incidence of sour rot in inoculated 'Temples'.**

Sour rot, caused by the fungus *Geotrichum candidum* Lk. ex Pers., is a decay of numerous fruits and vegetables, including citrus (5). In citrus fruits, the organism is a wound pathogen requiring injury into the albedo for entry. The decay is more prevalent as fruit increases in maturity. The specialty tangerine and other zipper-skinned varieties usually develop more sour rot than round oranges or grapefruit.

G. candidum is a filamentous fungus commonly found in citrus soils (4) and existing as a contaminant on the surface of the fruit. The fungus can accumulate with dirt and debris in dip tanks or drenchers where injured fruit may thus become infected. Fruit which decay during degreening can disintegrate on washer brushes distributing inoculum over the brushes and the conveying system of the packing line. Nest-

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[1] Florida Agricultural Experiment Stations Journal Series No. 1999.