methyl disulfide, methyl propyl disulfide, dipropyl disulfide, methyl propyl trisulfide, and some unidentified products.

From Ip 1500 it becomes difficult to distinguish odors at all, for a specific leeklike odor lasts around the collector exit.

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LITERATURE CITED

Bernhard, R. A., *J. Food Sci.* **33**, 298 (1968).
Boelens, H., Brandsma, L., *Recl. Trav. Chim. Pays-Bas* **91**, 141 (1972).
Boelens, M., de Valois, P. J., Wobben, H. J., van der Gen, A., *J. Agric. Food Chem.* **19**, 984 (1971).
Bouche, J., Verzele, M., *J. Gas Chromatogr.* **6**, 501 (1968).
Brodnitz, M. H., Pascale, J. V., *J. Agric. Food Chem.* **19**, 269 (1971).
Brodnitz, M. H., Pollock, C. L., Vallon, P. P., *J. Agric. Food Chem.* **17**, 760 (1969).
Calvallito, C. J., Bailey, J. H., *J. Am. Chem. Soc.* **66**, 1944 (1950).
Carson, J. F., in "Chemistry and Physiology of Flavors", Avi, Westport, Conn., 1967, p 390.
Dembele, S., Dubois, P., *Ann. Technol. Agric.* **22**, 121 (1973).
Johnson, A. E., Nursten, H. E., Williams, A. A., *Chem. Ind. (London)*, 556 (May 1971).
Macleod, A. J., *Flavour Ind.* (Oct 1970).
Rasquinho, L. M. A., *J. Gas Chromatogr.*, 340 (1965).
Schwimmer, S., Friedmann, M., *Flavour Ind.* (March 1972).
Schwimmer, S., Guadagni, D. G., *J. Food Sci.* **33**, 183 (1968).
Schwimmer, S., Weston, W. J., *J. Agric. Food Chem.* **9**, 301 (1961).
Stoll, A., Seebeck, E., *Helv. Chim. Acta* **31**, 189 (1948).
Stoll, A., Seebeck, E., *Helv. Chim. Acta* **32**, 197 (1949a).
Stoll, A., Seebeck, E., *Helv. Chim. Acta* **32**, 866 (1949b).
Stoll, A., Seebeck, E., *Adv. Enzymol.* **11**, 377 (1951).
Tonsbeek, Ch. H. Th., Koenders, E. B., van den Zijden, A. S. M., Losekoot, J. A., *J. Agric. Food Chem.* **16**, 1016 (1968).

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Effects of Storage Temperature and Container Lining on Some Quality Attributes of Papaya Nectar

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Papaya nectar in plain tin- and enamel-lined cans was stored at 55, 75, and 100°F for 1 year. Samples were analyzed periodically to determine quality of the product. Corrosion of the tin lining was most rapid at 100°F; after 1 year, the tin content of the nectar was 400 ppm. Iron content increased more rapidly in enamel- than in tin-lined cans. Acid hydrolysis of sucrose was a first-order reaction. The samples stored at 100°F were dark and of poor flavor. Samples at 55°F were virtually unchanged after a year. Type of can lining was not as important as low temperature for quality retention in storage.

Papaya is marketed chiefly as fresh fruit, but interest in its processed products such as canned nectar has increased. The nectar is made from papaya puree, water, sugar, and citric acid. The stability of canned papaya nectar, as of any processed food product, is important to the producer. Storage temperature and type of can lining generally affect the stability of a product.

Enamel-lined cans have been recommended for papaya nectar because of the corrosiveness of papaya products on plain, tin-lined cans (Lloyd, 1972). A positive correlation between nitrate content and rate of detinning has been established (Farrow et al., 1970; Board, 1973). Extensive detinning can cause container failure and may affect product flavor. Tolerance of tin in high acid foods has not been established in the U.S., but limitations have been imposed on the amount of $SnCl_2$ that can be added to some canned vegetables. No toxic effects were shown from ingestion of fruit juices that contained 730 ppm of Sn (Benoy et al., 1971).

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The characteristic carotenoid color of products is often, but not always, retained better in tin- than in enamel-lined cans (Payumo et al., 1968; Lloyd, 1972). The rate of darkening of fruit products has been associated with hydrolysis of sucrose to reducing sugars (Stadtman, 1948; Hodge, 1953; Loeffler, 1941), which then enter the Maillard reaction or other reactions producing brown pigments. Inversion of sucrose in a fruit juice product can thus be viewed as a phenomenon associated with the early stages of quality deterioration.

We report herein our investigation of the effects of storage temperature and type of can lining on quality and composition of papaya nectar.

MATERIALS AND METHODS

Papaya nectar (13.4° Brix; pH 3.5) was prepared from papaya puree (25%), water, and sugar (10%). The puree had been prepared by the method of Brekke et al. (1972) and stored at 0°F for 1 year.

Half of the nectar (about 150 lb) was then canned in enamel-lined cans (G enamel; no side seam spray, 0.25 lb electrolytic inside, 1.00 lb electrolytic outside, MR 85 lb tin plate). The remaining 150 lb was canned in differential bright tin plate (1.00 lb inside and 0.5 lb outside). After vacuum sealing, the cans were spin-cooked in flowing steam for 3 min (Wang and Ross, 1965), then spin-cooled in water

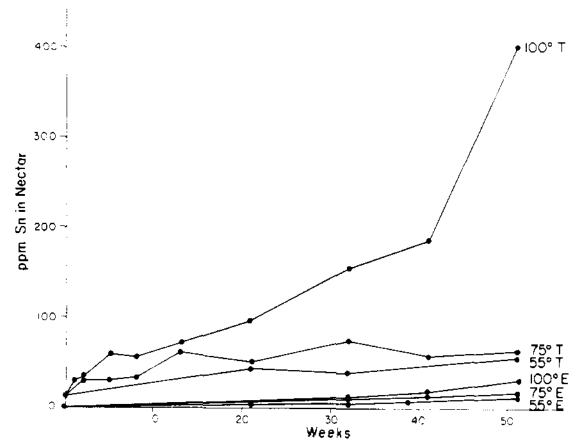

Figure 1. Tin content of papaya nectar stored in tin-lined (T) and enamel-lined (E) cans at 55, 75, and 100° F.

sprays for 3 min. Several cans of each lot were then stored at 0, 55, 75, and 100°F.

At intervals of several weeks, cans were withdrawn from storage; the nectars were informally tasted, and the interiors of the cans examined for signs of corrosion. Total and reducing sugars were assayed by the Nelson–Somogyi method. Soluble solids were determined with an Abbe type refractometer.

Fe and Sn concentrations in papaya nectars were measured at 248.8 and 224.6 nm, respectively, with a Perkin-Elmer Model 303 atomic absorption spectrophotometer. A digital concentration readout accessory was used for the determination of Fe, and a Texas Instrument Servoriter II Recorder at 10× expansion recorded Sn concentration. The samples, after appropriate dilution and acidification to 1.0 N HCl, were aspirated through a 3-slot Boling burner, fueled by air–acetylene. Filtration or centrifugation of the nectars prior to analysis prevented clogging. Fe standards were prepared from reagent grade Fe metal, and Sn standards from $SnCl_2$.

At the end of 32 weeks, nectars stored at the two highest temperatures (75 and 100°F) were evaluated formally by an experienced taste panel. Eleven judges evaluated flavor quality, rating the samples on a 7-point quality scale where 7 = excellent and 1 = unacceptable. The nectars were served at 55°F to judges in individual taste booths equipped with red illumination.

For color measurements, about 0.5% of Pectinol 10-M was stirred into nectar, which was then allowed to stand at room temperature (75°F) for 30 min. The mixture was filtered in vacuo through a pad of Filtercel, and the absorbance of the filtrate compared to water was determined at 400 nm with a Spectronic 20 colorimeter.

RESULTS AND DISCUSSION

Quality of the samples held at 100°F deteriorated the most rapidly, as expected. Corrosion increased with temperature, as indicated by the rate of accumulation of Sn and Fe in the nectar. At 55°F for 51 weeks, tin linings were very slightly etched in small areas, and enamel linings had few faint vertical lines of abrasion. At 51 weeks, the tin linings held at 75°F were moderately etched; those held at 100°F were extensively detinned, and exposed steel surfaces were black. At 51 weeks, the enamel linings held at 75°F were very slightly corroded around the top, or lap, of the side seam and had one or two vertical black streaks; the enamel linings at 100°F were corroded at many spots along the side seam and had several wide, vertical black streaks.

Figure 1 shows that nectars in tin-lined cans held at 100

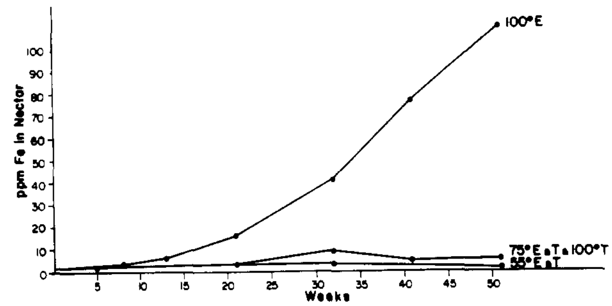

Figure 2. Iron content of papaya nectar stored in tin-lined (T) and enamel-lined (E) cans at 55, 75, and 100° F.

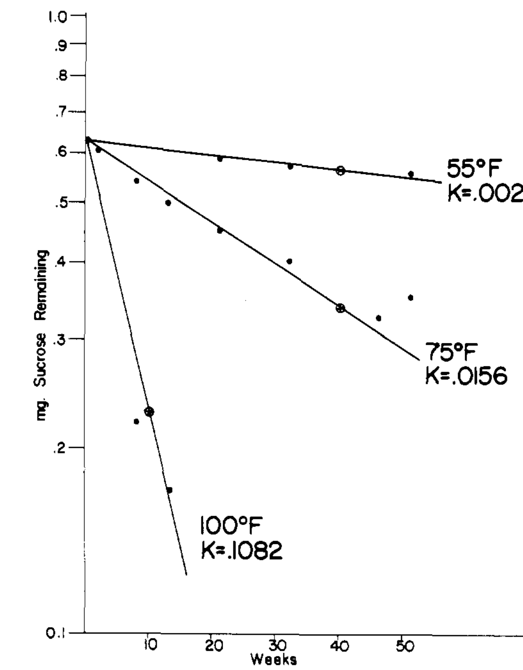

Figure 3. Influence of temperature on amount of sucrose remaining in 6.4 mg of papaya nectar after storage.

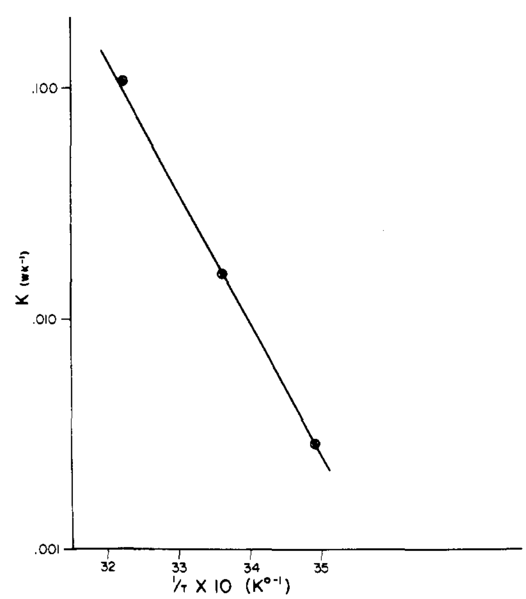

Figure 4. Influence of temperature on first-order reaction rate constant for sucrose hydrolysis in papaya nectar.

and 55°F for 51 weeks had 400 and about 60 ppm of tin, respectively. Initially, the samples had about 12 ppm of Sn, attributed to dissolution of Sn from the can lining during heat processing. At 51 weeks, the Sn content of

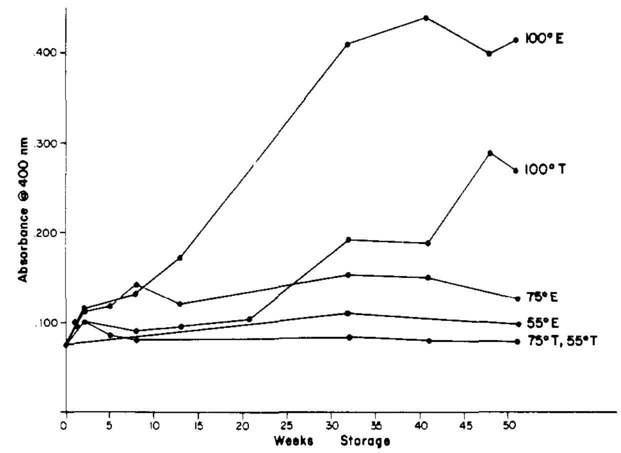

Figure 5. Absorbance (400 nm) of papaya nectar filtrates after storage at 55, 75, and 100°F.

Table I. Average Flavor Quality Ratings of Papaya Nectars Stored 32 Weeks[a]

Container lining	Storage temp, °F 75	100
Tin	4.8	3.2
Enamel	4.6	3.0

[a] Scores connected by the same line are not significantly different.

samples in enamelled cans was below 40 ppm, and was probably due to corrosion noted along the side seams.

The Fe content of samples in enamel-lined cans held at 100°F for 51 weeks was 110 ppm (Figure 2). The enamel lining had obviously been breached in several places, and the exposed steel was corroded. The Fe content of nectar in plain, tin-lined cans was only 9 ppm after 51 weeks at 100°F. The tin lining more effectively prevented the corrosion of the underlying steel than did the enamel.

The decrease of sucrose in the nectar was attributed to acid hydrolysis. The amounts of sucrose remaining in 6.4 mg of nectar are shown in Figure 3. The semi-log plot suggests that the hydrolysis was a first-order reaction; the rate constants were calculated for each storage temperature. The activation energy, calculated to be 25600 cal/mol, agreed closely with that reported by Lund et al. (1969) for a model system at temperatures above freezing. The Arrhenius plot was linear over the temperature range involved (Figure 4). The decrease in sucrose content correlated with an increase in reducing sugars; the total sugar content did not change during storage. Nectars in enamelled cans stored at 100°F darkened, or browned substantially, and color at 32 weeks was judged unacceptable. The absorbances of clear filtrates of nectars (Figure 5) were higher for samples that were noticeably brown. The lower absorbances of samples from tin- as compared to enamel-lined cans indicated a bleaching effect by the tin lining.

Judges observed a significant difference between samples stored at 75 and 100°F (Table I); the latter samples were of lower flavor quality. However, significant quality difference between samples in tin- and enamel-lined cans was not observed.

We conclude that papaya nectar should be stored at 75°F or below, and that either tin- or enamel-lined cans, as used in this study, would be satisfactory.

LITERATURE CITED

Benoy, C. J., Hooper, P. A., Schneider, R., *Food Cosmet. Toxicol.* **9**, 645 (1971).
Board, P. W., *Food Technol. Aust.* **25**(1), 15 (1973).
Brekke, J. E., Chan, H. T., Jr., Cavaletto, C. G., *Food Prod. Dev.* **6**(6), 36 (1972).
Farrow, R. P., Lao, N. T., Kim, E. S., *J. Food Sci.* **35**, 818 (1970).
Hodge, J. E., *J. Agric. Food Chem.* **1**, 928 (1953).
Lloyd, A. C., *Queensl. J. Agric. Anim. Sci.* **29**, 85 (1972).
Loeffler, H. J., *Ind. Eng. Chem.* **33**, 1308 (1941).
Lund, D. B., Fennema, O., Powrie, W. D., *J. Food Sci.* **34**, 378 (1969).
Payumo, E. M., Pilac, L. M., Maniquis, P. L., Philip, J., *Science* **97**, 127 (1968).
Stadtman, E. R., *Adv. Food Res.* **1**, 325 (1948).
Wang, J-K., Ross, E., *Agric. Eng.* **46**, 154 (1965).

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