COLD STORAGE EFFECTS ON FRESH MARKET PE

Estimating freezing points

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Fruits for fresh market distribution commonly are stored under refrigeration in or near areas where they are grown. Cold storage delays ripening. The effective maketing season is expanded, and the advantages of greater shelf life potential for the product can be passed on to the consumer. However, many varieties of California peaches, nectarines, and plums are subject to a low-temperature internal breakdown that may (1) limit the time fruit can be held and still ripened normally; or may (2) produce internal browning, (3) mealiness, or (4) combinations of the above.

The two articles presented here report research to determine the critical temperature levels at which fruit can be held with least danger of either freezing or internal breakdown. These levels are correlated with soluble solids, or fruit sugar levels. Generally, breakdown is most severe under storage between 2.2 to 5° C (36 to 41° F), and least severe at or near 0° C (32° F). Temperatures above 5° C (41° F) result in rapid tissue softening and quicker ripening. There are indications, however, that periodic exposure of low temperature fruit to temperatures in the 20 to 40° C range (68 to 104° F) delays onset of breakdown, but this requires further study.

SUSCEPTIBILITY to freezing is an important concern in any fresh fruit cooling and storage program. While many fruits benefit from storage at or even below 0°C (32°F), any temperature management recommendations must ensure product safety from freezing. More precise temperature management practices are aimed at reducing internal breakdown losses in nectarines, peaches and plums.

Freezing point information is available on some of these fruits, but most fresh-market varieties are recent introductions for which data are not available. Also, within species, freezing points may differ among varieties. Further, an adequate statistical relationship is lacking between freezing point and normal field determinations of soluble solids. The tests reported here were conducted to gather this information for some major commercial varieties of these fruits.

Fruit tested was from commercially packed lots of 19 varieties of nectarines, peaches, and plums. Soluble solids were measured using normal commercial procedures—juice squeezed from a wedge slice from one cheek of each fruit was read with a refractometer. Twenty-two fruits of each variety tested, representing the range of soluble solids within that variety, were selected for freezing point determinations.

Determinations

Freezing point determinations were made in a refrigerated room held at -6 ± 1°C (21 ± 2°F). Thermocouples, attached to a thermograph, were placed in the uncut cheek of the fruit near the pit and the temperature of each fruit was recorded every four minutes. The thermograph standardization and measuring procedures were designed to assure accuracy in reading to 0.05°C (0.1°F). Temperatures of all fruits were recorded throughout the cooling period. *The freezing point is readily determined* in such a system: the fruit tissue first supercools to a temperature below its freezing point; then, as ice crystals form, the temperature rises and temporarily forms a distinct plateau or shoulder that is the fruit's freezing point. In our system, plateaus held for 30 to 45 minutes, providing easy determinations of freezing points.

Results

The table shows the lowest soluble solids and highest freezing points for each of the varieties studied. The highest freezing point for each variety is included because of its importance in avoiding freezing damage in commercial use.

Also shown is the coefficient of correlation between soluble solids and freezing point. Soluble solids measurements generally provided a reasonably good estimate of freezing point (overall coefficient of correlation = -0.79). A perfect correlation would be -1.00 (the lower the soluble solids, the higher the freezing point). A complete lack of correlation would be represented by 0 value. Deviations from perfect correlation (values greater than -1.00) are assumed to be due to the heterogeneous nature of the fruits tested.

It is recognized that higher correlations could be achieved in these tests by measuring soluble solids and freezing points of extracted juice or pulp. However, since the primary purpose of the study is to prepare commercial recommendations for fruit cooling and handling, the heterogeneous nature of the fruit tissue must be considered. That the deviation from perfect correlation between soluble solids and freezing point is due primarily to heterogeneity is shown by comparing the coefficients of correlation for intact fruits with those of the pulp slurries for three of the test varieties. For September Grand nectarine, the figure for intact fruit was -0.72, and the figure for the pulp slurry was -0.97. The same figures for Casselman plum were -0.75 and -0.98, respectively. For Pageant peach the figures were -0.59 and -0.97.

Regression curve

The overall regression curve (see graph) is constructed from data on 484 individual fruit determinations for all 19 test varieties. This curve may be useful in estimating the lowest safe storage temperature for any variety, assuming reliable information is available on the lowest soluble solids content of that fruit. The upper dotted line provides a reasonable confidence limit (95%), taking into account the variability in individual fruits. Note that, in general, tested varieties showing poorest correlation between soluble solids and freezing point (see table), are those with a reputation for the greatest unevenness in ripening within individual fruits.

ACHES, NECTARINES & PLUMS

Using low temperatures to delay internal breakdown

LOSSES OF CALIFORNIA peaches and nectarines have occurred in recent seasons from a low-temperature related breakdown of the fruit flesh during storage and distribution. This internal breakdown has been reported in some peach varieties for many years. During the past ten years, a similar problem has been observed in late-season nectarine varieties in California. Internal breakdown does not occur at 10°C (50°F) or above, but rapid ripening and senescence preclude holding these fruit at such a high temperature. The breakdown appears rapidly and severely at 5°C (41°F), and less rapidly and somewhat less severely at 0°C (32°F). Research in other parts of the world suggests various procedures to reduce the problem, including warm-temperature conditioning treatments before or during storage, and the use of controlled atmospheres. These were not successful in earlier limited tests in California.

In 1972 and 1973, a University of California study compared the susceptibility of nine nectarine and six peach varieties to low-temperature breakdown as influenced by various storage temperatures. In addition, the deteriorative effect of simulated rail transit for one week at 5°C (41°F), following 0°C (32°F) storage, was studied on five highly susceptible nectarine varieties. Other limited tests explored the effects on internal breakdown of periodic exposure to elevated temperatures during the storage period.

COMPARISON OF FREEZING POINTS AND SOLUBLE SOLIDS IN NECTARINES, PEACHES AND PLUMS, 1972.

Variety	Lowest soluble solids	Highest freezing point	correlation of correlation
	%	°F	
Peach			
Suncrest	7.2	30.3	−0.71
Fortyniner	8.8	29.7	−0.78
Fay Elberta	8.0	29.8	−0.46
Fiesta	8.2	29.9	−0.94
Pageant	8.3	30.0	−0.59
Halloween	9.2	29.8	−0.68
Six peach varieties*	7.2	30.3	−0.80
Plum			
Simka	11.6	29.2	−0.86
Queen Ann	6.4	29.9	−0.90
Nubiana	7.2	29.8	−0.78
Casselman	10.2	28.7	−0.75
Four plum varieties*	6.4	29.9	−0.85
Nectarine			
Red June	6.6	30.1	−0.48
Early Sun Grand	7.9	30.0	−0.74
Independence	7.2	29.8	−0.81
Red Grand	8.6	29.7	−0.81
Le Grand	7.6	30.1	−0.86
Gold King	9.6	29.5	−0.56
Regal Grand	8.6	30.0	−0.81
September Grand	8.7	29.5	−0.72
Autumn Grand	8.3	30.1	−0.74
Nine nectarine varieties*	6.6	30.1	−0.72
Nineteen test varieties*	6.4	30.3	−0.79

* Values shown are the lowest soluble solids, highest freezing points, and average correlation coefficient for the groups of varieties indicated.

Susceptibility to breakdown

Commercially-packed fruit of each test variety was obtained at packing houses and placed at storage temperatures of 0°, 5°, and 10°C (32°, 41°, and 50°F) on the day of harvest. Five additional late nectarine varieties were stored at 2.2° and 7.8°C (36° and 46°F). All fruits were equalized to the holding temperature within 24 hours after harvest. Fruit firmness was measured at harvest and at removal from storage. Soluble solids were measured at harvest and during evaluation after ripening.

Starting two weeks after harvest and continuing for up to eight weeks, samples were drawn each week from each treatment, ripened for approximately five days at 20°C (68°F), and scored for internal browning (breakdown) and flesh mealiness.

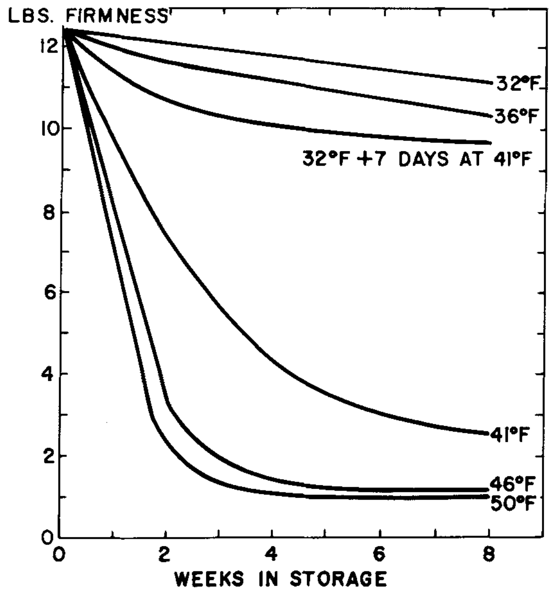
Based upon these evaluations the test varieties were divided into three groups according to breakdown symptoms: (1) no browning, mealiness mild or lacking (Early Sun Grand, Independence, and Red Grand nectarines); (2) browning mild or lacking, severe mealiness (Red June nectarine; Fay Elberta and Fortyniner peaches); and (3) severe browning and mealiness (Autumn Grand, Gold King, Le Grand, Regal Grand, and September Grand nectarines; Fiesta, Suncrest, Halloween, and Pageant peaches). Severe symptoms of external browning were also expressed by the Suncrest variety. Late Le Grand and Sun Free nectarines may be added to the third group based on previous observations.

Storage temperature

No variety showed internal breakdown symptoms at 10°C (50°F), but that temperature is unsatisfactory because of rapid flesh softening. At 7.8°C (46°F) symptoms generally appeared in susceptible varieties, but were rated as mild. Storage at 5°C (41°F) resulted in rapid loss of market life for all susceptible varieties, with the fruit considered unmarketable after one to two weeks.

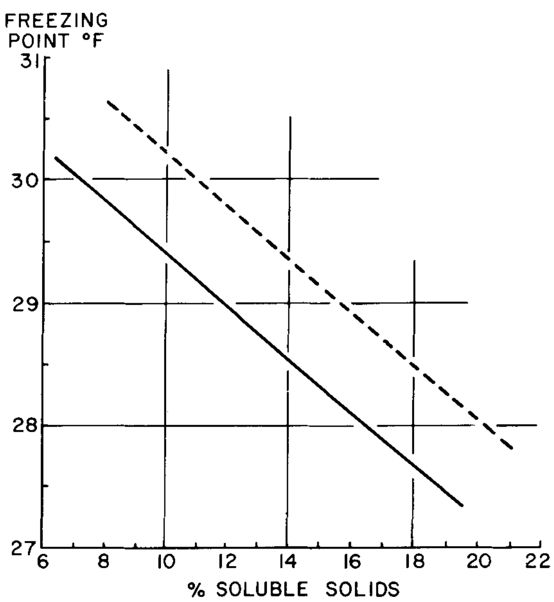
The five late nectarine varieties (group 3) stored at 2.2°C (36°F) developed browning and mealiness almost as fast as those at 5°C (41°F). Following long storage (six to eight weeks) the symptoms were more severe. Thus, 2.2°C (36°F) storage shows no advantage

FIRMNESS MEASUREMENTS FOR FIVE LATE NECTARINE VARIETIES HELD UNDER SEVEN DIFFERENT STORAGE TREATMENTS. NOTE THAT FRUIT STORED AT 2.2°C (36°F) LOST FIRMNESS SLOWLY, WHILE FRUIT STORED AT 5°C (41°F) LOST FIRMNESS RAPIDLY.



FREEZING POINT ESTIMATES FOR 19 VARIETIES OF NECTARINE, PEACH, AND PLUM, 1972.

Solid line is the linear regression curve (essentially the average) for 484 individual fruit measurements, and the dotted line represents the upper limit of a 95% zone of estimate for the 19 varieties (95% of all freezing point measurements would be expected to fall below this line).



over 5°C (41°F) storage for the nectarines tested.

Following 0°C (32°F) storage, all susceptible varieties developed internal breakdown, but the expression of symptoms was delayed and less severe than in fruits stored at 2.2° or 5°C (36° or 41°F).

Transit after storage

Following storage, late nectarines are commonly shipped by rail with transit periods of seven days or more at temperatures near 5°C (41°F). To evaluate the development of internal breakdown under these conditions, weekly samples of five late season nectarine varieties (Le Grand, Regal Grand, Gold King, September Grand and Autumn Grand) were drawn from 0°C (32°F) storage and transferred to 5°C (41°F) for seven days before ripening. This treatment accelerated development of internal browning in all varieties and reduced market life by approximately one week, the period of exposure to the higher transit temperature. September Grand and Gold King were least affected; Le Grand was most affected.

Flesh firmness changes

Weekly measurements of flesh firmness were made on fruit from all lots at time of removal from storage. The rates of softening during storage differed markedly between fruit held at 2.2°C (36°F), or below, and fruit held at 5°C (41°F), or above (see graph). Data are shown only for the five late nectarine varieties because of the greater number of storage temperature treatments used. However, the same pattern was evident between 0°, 5°, and 10°C (32°, 41°, and 50°F) storage for all 15 test varieties of both nectarines and peaches.

Market life at 0°C

Based on accumulated data, the estimated market life for all test varieties held at 0°C (32°F) is as follows: Early Sun Grand—six weeks; Independence, Red Grand, Le Grand, and Gold King—five weeks; Red June, Regal Grand, September Grand, Fortyniner, and Fay Elberta—four weeks; Autumn Grand—three weeks; Suncrest and Fiesta—two weeks; and Pageant and Halloween—one week.

Effect of periodic warming

The value of periodic warming of fruit to interrupt constant low-temperature storage was explored. Warming fruit 20 to 25°C (68 to 77°F) had been reported to delay internal breakdown of peaches, but at the cost of rapid fruit softening. However, recent work suggests that fruit softening may be slowed at 40°C (104°F). In these tests, a weekly, 15-hour interruption of storage at either 20°C (68°F) or 40°C (104°F) slowed the development of internal browning. Fruit treated at 40°C (104°F) was judged firm enough to ship (6.6 to 8 lbs firmness), and some lots of fruit were classified as still juicy and flavorful at the end of the eight-week storage test. Fruit treated at 20°C (68°F) softened to less than 6 lbs firmness within two weeks. While these results provide a basis for further study, the commercial possibilities are uncertain.

Conclusions

Storage of any variety should be as near 0°C (32°F) as possible without danger of freezing the product. For all varieties, this low temperature is important in slowing the rate of flesh softening to obtain as long a market life as possible. For most varieties, this low temperature is essential in slowing the development of mealiness and browning during extended storage. Temperatures below 0°C (32°F) may be practical for high maturity, high-soluble-solids fruit of some varieties. Danger of fruit freezing is the only concern in lower temperature storage.

Storage at 2.2°C (36°F) to 5°C (41°F) should be avoided. Browning and mealiness develop quickly, and symptoms become extremely severe in this temperature range.

Extended transit at around 5°C (41°F) should be avoided. Ways of achieving low transit temperatures should be explored, particularly near the end of the storage life of a variety. Truck transport might be considered as a means of reducing transit time.

Varieties known to have a very short market life should not be stored. Their successful marketing will depend on rapid, thorough cooling to 0°C (32°F) and immediate distribution, preferably at a low transit temperature.

In the absence of adequate data, rapid and thorough cooling should be considered as essential for all varieties. All fruit used in tests reported here were cooled to storage temperature within 24 hours of harvest.

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ENERGY

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HIGH FEED PRICES last year caused many dairymen to feed their herds poor quality roughages and to reduce both the quantity and quality of concentrates. The result was much lower milk production in many herds all over the state. In some cases, reduced milk production due to poor feeding practices resulted in less income above feed cost than if the feeding program had remained the same (in spite of high feed prices).

Although there is a continuing trend toward increased feeding of corn silage, oat silage, and other forages to dairy cows in California, alfalfa hay remains the predominant forage fed to dairy cows. About five million tons of alfalfa hay are fed to dairy cattle in California each year, which was about 70% of the seven-million-ton alfalfa hay crop in 1973. Good quality alfalfa hay is an ex-excellent forage for dairy cattle. Its availability in the past has been one of the primary reasons that California dairy cows have the highest average milk production in the United States.

Fiber and energy

There is a very close relationship between the fiber and energy content of alfalfa hay. As the alfalfa plant matures, it becomes more fibrous and contains less energy per unit of dry matter. Dairymen know that hay with lower crude fiber content results in higher milk production. This is partially due to the higher energy content of the low-fiber hay, and partially due to the fact that cows like it better and eat more. Additionally, low-fiber hay is higher in protein, minerals, and vitamins. This makes it possible to feed a less expensive concentrate mix without sacrificing milk production.

Even high-quality roughages limit milk production by filling the rumen to capacity before all nutrient needs are met. Energy in the form of grains and other concentrates must be provided to realize the full potential of high-producing cows. They cannot consume enough roughage to fulfill their energy needs for high milk production.

It would seem that the more concentrates fed, the better it would be for the high-producing cow. However, it becomes eventually impossible to increase energy any further without lowering fiber con-