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Editor

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EFFECT OF FRUIT MATURITY AND STORAGE TEMPERATURE ON THE INCIDENCE OF BLACK HEART DISORDER IN 'SEURI' ASIAN PEAR

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In the Central Valley, brown spots occurred in Asian pear flesh after storage during the 1990 and 1991 seasons. This problem is called black heart disorder in New Zealand, Australia, Japan and China. Black heart disorder appears along and around the vascular bundles and there is no visual indication from outside of the fruit. It limits opportunities to grow and market Asian pears. Black heart disorder begins in 'Ya-Li', 'Seuri', 'Dan Be', 'Hosui', and 'Shingo' Asian pear cvs. while they are still on the tree but, it becomes more severe with storage.

The cause of the black heart disorder is unknown. Climatic factors, i.e., fluctuating hot and cool temperatures during summer, or high rainfall right before harvest have been implicated in Japan (Anon, 1978) and New Zealand (Lallu, 1990). Black heart disorder has been more frequently observed on the sun-exposed side of the fruit or under obvious sunburns (Kawai, 1990). Rapid cooling at the beginning of storage has also been associated with more severe black heart disorder symptoms (Lallu, 1990).

For these reasons, we decided to carry out a preliminary evaluation of the effect of fruit maturity and storage temperature on the storage performance of 'Seuri' Asian pear.

Plans and Procedures:

1. **Influence of Storage Temperature on Black Heart Disorder Incidence in 'Seuri' Asian Pear**

   To study the effect of storage temperature on the incidence of black heart in 'Seuri' pears, three boxes (size 18) per each of the three temperature treatments were placed in storage to be evaluated after 1, 2, and 3 months. Because there was so much black heart after one month storage, the storage trial was terminated at this point. All three boxes per temperature treatment were evaluated for disorder incidence and quality parameters (soluble solids content and firmness).

Results

1. Influence of Storage Temperature on Black Heart Disorder Incidence of 'Seuri' Asian Pear

Storage temperatures equal to or below 50°F (10°C) did not influence the percentage of fruits presenting the black heart disorder or fruit quality parameters (Table 1). After one month storage at 32°, 41° and 50°F; 50%, 56% and 61% of the 'Seuri' pears showed the black heart disorder, respectively. Also, firmness and soluble solids content were not affected by any of the storage temperatures tested in this trial.

Table 1. Influence of different storage temperatures on firmness, soluble solids content and incidence of black heart disorder of 'Seuri' Asian pear after 30 days storage. (Kearney Agricultural Center, 1991).

Temperature	Firmness (pounds)	SSC (%)	Fruit with Black Heart Disorder: % of fruits	Fruit with Black Heart Disorder: Ave. % area
32°F (0°C)	12.8 a[z]	13.4 a	50 a	85 a
41°F (5°C)	13.1 a	13.5 a	56 a	85 a
50°F (10°C)	12.7 a	13.7 a	61 a	60 b

[z] Same letters within a column indicates no significant differences by the LSD means separation test (5%).

Disorder intensity was evaluated as the percentage of the fruit area presenting this disorder. This index was lower on the fruit stored at 50°F; and there was no difference in the intensity of this disorder for fruits stored at 32° and 41°.

2. Influence of pear calyx end color measured after one month of storage at 32°F on the incidence of black heart disorder in 'Seuri' Asian pear and maturity parameters.

Calyx color as measured visually after one month storage by gently scraping the bottom of the pear (calyx end) with a razor blade, was associated with the incidence of black heart on 'Seuri' Asian pear. Green colored pears did not have any flesh discoloration while 90% of the yellow colored pears did.

Table 2. Influence of one month storage at 32°F (0°C) on the firmness, soluble solids content and incidence of black heart disorder of green and yellow 'Seuri' Asian pears (Kearney Agricultural Center, 1991).

Skin color	Firmness (pounds)	SSC (%)	Fruit with Black Heart Disorder: % of fruits	Fruit with Black Heart Disorder: Ave. % area
Yellow	12.5	14.1	90	90
Green	13.2	12.6	0	0

Comments:

This preliminary data shows the possible relationship between fruit maturity and the development of black heart disorder. A more detailed study with a special emphasis on the interaction between storage temperature and physiological maturity needs to be done. A practical method to measure fruit maturity should be developed.

RELIABILITY OF FRUIT COLOR AS A MATURITY INDEX FOR 'TWENTIETH CENTURY' ASIAN PEAR GROWN UNDER CENTRAL VALLEY CONDITIONS

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In the Pacific Northwest, there were some enquiries about the brown spots found in 'Ya-Li', 'Dan Be', 'Hosui' and 'Shingo' Asian pear flesh after storage during the 1990 season. This disorder is known as flesh spot decay (FSD) in New Zealand and Australia, and limits opportunities to grow and market Asian pears. In New Zealand, large size 'Nijisseiki' (Twentieth Century') fruits are so badly affected by FSD that their exportation has decreased since the late 1980's (Kawai, 1990). In Australia, FSD was obvious on 'Nijisseiki' when the trees were thinned hard to produce fruit weighing 300 grams or larger (Kawai, 1990). Japan also has a problem, but it depends on the climate during the season. From 1970 to 1985, when the emphasis of the Asian pear industry was on production of large fruit, the FSD problem was especially severe (Anon, 1986). However, it has nearly been overcome by soil amelioration; i.e., deep cultivation and use of organic fertilizers (personal communication with Dr. Yoneyama in Tottori, Japan).

The objective of this work was to study the effect of fruit maturity (fruit color) on fruit quality, and FSD development on 'Twentieth Century' Asian pear.

Plans and Procedures:

At the commercial harvest time, fruits were collected and separated into three categories according to their ground color. Color evaluation was measured at the calyx end by using the Japanese color chart (Kajiura et al., 1975). Fruits were packed into 20 pound boxes without polyliners and stored at 32^{o}F (0^{o}C) for a 4 month period. Fruit quality evaluation including fruit firmness, soluble solids concentration, pH, acidity, starch and Flesh Spot Decay (FSD) incidence were measured at harvest time and after 4 months storage period.

Results

There were no significant differences in fruit firmness, soluble solids content, fruit weight and FSD incidence measured at the harvest time (Table 1).

Table 1. Influence of pear calyx end color at harvest on '20th Century' Asian pear fruit characteristics measured at harvest (August 20, 1991).

Color[z] (calyx)	Fruit weight (g)	Firmness (lbs)	SSC (%)	FSD incidence (no. spots/fruit)
1.5	257 a[y]	12.9 a	11.5 a	0.1 a
2.5	231 a	12.9 a	11.8 a	0.2 a
3.7	220 a	12.5 a	12.0 a	0.1 a

[z] Color measured according to Japanese color chart.
[y] Means separation by LSD test (P = 0.05). Same letters within a column indicates no significant differences.

Fruit characteristics measured after the 4 month storage period were not affected by calyx end color measured at harvest. At this time, fruit had a firmness near 11.0 pounds and 13.8 SSC%. Water loss values expressed as percentage of initial weight loss were close to 5.0%, however, water loss symptoms were not observed in any of the treatments (Table 2).

Table 2. Influence of pear calyx end color at harvest on '20th Century' Asian pear fruit characteristics measured 4 months after storage at 32^{o}F (0^{o}C).

Color[z] (calyx)	Fruit weight (g)	Water loss (% initial weight)	Firmness (lbs)	SSC (%)	Color (score)[y]	FSD incidence (no. spots per fruit)
1.5	249 a[x]	4.8 a	11.3 a	13.8 a	1.2 a	0.24 a
2.5	234 a	4.9 a	10.9 a	13.8 a	1.5 ab	0.15 a
3.7	229 a	4.2 a	10.7 a	13.9 a	2.1 b	0.22 a

[z] Color measured according to Japanese color chart.
[y] 1 = green, 2 = light yellow and 3 = dark yellow.
[x] Means separation by LSD test (P = 0.05). Same letters within a column indicates no significant differences.

Comments:

Recent information indicates that water loss symptoms such as fruit shrivelling begin to become visible after 8-10% water loss. This data points out the importance of reducing water losses during handling and storage operations in Asian pears. The use of polyliners are suggested for long storage situations. The incidence of FSD was not important at all. We observed only a few cases which showed one or two tiny spots, almost not visible. These few cases were observed just on over-ripe and large size fruit (over 300 g). Unfortunately, only a few fruit reached the 300 g plus size in this trial so the effect of large fruit size on FSD development was not studied in detail. Information from

New Zealand (Lallu et al., 1990) recommends a 3 month storage period for 'Twentieth Century' when it is picked at a score of 2 or 3 on the Japanese color chart. In our situation, after a 4 month storage period, fruits were in good condition in all of the treatments. Only more uniform yellow fruit color was obtained on fruits harvested between the 2-3 color score measured at the calyx end measured at harvest time.

Based on our preliminary results we suggest picking 'Twentieth Century' around the color score 3 to obtain the maximum fruit quality, storage potential and fruit size. The final storage potential for 'Twentieth Century' could be longer than 4 months if water loss is reduced during postharvest operations.

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TIPS FOR LONG TERM STORAGE OF KIWIFRUIT

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As most of California kiwifruit production is located in the Central Valley, a short summary of recommendations to produce high quality kiwifruit are given:

1. Minimum maturity of kiwifruit in California is still 6.5 percent soluble solids content. Taste evaluations indicate that satisfactory flavor is achieved when ripe fruit reaches at least 14 percent soluble solids content (at consumption).

2. Prediction of ripened soluble solids content (SSC) by the relationship between SSC and total solids at harvest (microwave test) is still being developed. Investigations to understand this relationship and to determine non-destructive measurements of total solids as a maturity index are being carried out.

3. Research has shown kiwifruit with lower nitrogen levels retain their firmness better in long term storage. Therefore, there might be an advantage to cutting back on nitrogen fertilization in order to extend storage life. Also, this information can be used to help decide which fruit should be marketed quickly and which can be left longer in storage.

4. In general, late harvested kiwifruit will retain their flesh firmness during storage better than early harvested fruit. Late harvested kiwifruit will also present higher SSC at harvest and after storage.

5. Reduction of fruit injury during harvesting can be done by picking fruit at 14 pounds firmness or higher (8 mm tip) and avoiding drops and abrasion during transport. Reduction of vibration injury after storage can be done by transporting fruit to market at five pounds firmness or higher.

6. Botrytis infection can be kept under control by keeping the vineyard clean; avoiding fruit injury during harvest, transport and handling; brushing the fruit to remove

dead floral parts, particularly sepals, cooling the fruit rapidly and maintaining a constant storage temperature. Fruit from vineyards with a history of Botrytis decay should be stored separately. Because Botrytis decaying fruit in storage affects the softening of healthy fruit, frequent sorting of these fruit is suggested to avoid further losses.

7. The lowest temperature above freezing is the best storage temperature. Early harvested fruit should be stored at 33°F and late harvested fruit at 32°F flesh temperature.

8. Avoid ethylene exposure during harvest, transport and storage. Even very low ethylene levels (5-10 ppb) will induce fruit softening. Continuous ventilation during air storage helps to assure low ethylene levels (venting method, F. Gordon Mitchell). This method works very well in the Central Valley when the outside air is ethylene free. During burning days, we found that air ethylene levels increase.

MATURITY AND STORAGE OF APPLE VARIETIES NEW TO WASHINGTON STATE - 1992

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Numerous requests have been received from growers, fieldmen and warehouse managers for information on how to determine the picking date of apple varieties new to Washington State. The Washington State Tree Fruit Postharvest Conference held in March brought together a number of research and extension scientists to address this subject and some of their information is presented here.

Summarized below is what we currently know about the maturation process and storage potential of these new apple varieties. This information is preliminary and new studies will undoubtedly improve the information presently available. I would appreciate feedback from the industry regarding experiences with these new varieties.

FUJI

'Fuji', which is extremely popular in Japan, was selected from a cross of 'Ralls Janet' x 'Delicious'. It is a late-maturing apple with harvest beginning in mid-October in Washington. Fruit size is medium to large. Depending on the strain, it is striped or blush over a yellow-green ground color. There are several strains of 'Fuji' in Washington State and more strains that are not yet available here. In Japan, 'Fuji' apples for the specialty gift market are bagged while on the tree. It is very susceptible to alternate bearing.

Maturity

'Fuji' appearance is variable. Its skin color goes from a dull muddy brown to a clear bright red. 'Fuji' apples growing on light crop trees mature earlier than on well-cropped trees by as much as 10 days. 'Fujis' grown on weak fruiting wood or late flowering young spurs mature later than fruit borne on older wood. Fruit on young and vigorous trees has the dull muddy appearance while fruit on older trees is usually more attractive.

This variety requires several pickings. In Tasmania, Australia, it is recommended that the first picking include all light crop fruit. The main picking would include normally cropped trees except fruit on 1-year wood. The third and final picking includes fruit on 1-year wood, which is usually of lower quality.

Soluble solids concentration has not been a useful guide since seasonal variation and cropping levels cause large variations. For example, soluble solids can range from 12% in one year to 16% the next. Washington-grown 'Fujis' have been tested at 17-19% soluble solids. Flesh firmness is also one a suitable harvest indicator.

Some people are harvesting at the first sign of watercore in the more mature fruit on the tree. Selection of fruit to harvest should be determined by ground color. By the time the fruit reach a golden yellow ground color, most apples will have severe watercore. Tests in Washington State have shown that these apples are ready for harvest when they start to lose their green background color.

Storage

'Fujis' have a reputation as keeping well in long-term storage, even regular storage. However, in one test, soluble solids content did not rise during storage and firmness declined slowly over time. Washington 'Fujis' stored in regular storage at 32-33^{o}F until June remained above 15 lbs firmness.

'Fuji' apples have been stored in CA with results depending upon length of storage and the maturity of the fruit. In one test, flesh firmness after CA storage was almost 3 lbs above that in regular storage. There was no difference in soluble solids content.

Potential Storage Disorders

Scald - 'Fujis' are susceptible to storage scald and DPA is needed to minimize scald. Very low oxygen levels or initial oxygen stress might be helpful in reducing scald.

Rotting - 'Fuji' apples sometimes develop storage rots. Their thin skin makes them very susceptible. A prestorage fungicide should help reduce rot.

Watercore - Severe watercore can develop in 'Fuji' very early in the harvest season. There are reports that slight to moderate watercore in 'Fujis' may disappear if not too severe.

Coreflush - Internal core browning has been reported to be a problem with Washington-grown 'Fujis'. Browning begins around the core line and may even be present in some fruits at harvest.

Moldy core - In one test in Australia, 5% of the stored 'Fuji' apples developed moldy core.

Shrivel - Since 'Fuji' has a thin skin and produces very little natural wax it is prone to shrivel, especially in storage with low humidity.

GALA

'Gala' was selected in New Zealand from a cross between 'Kidd's Orange Red' and 'Golden Delicious.' It is the most widely planted of the apple varieties introduced into Washington State over the last 5 years. There are a number of 'Gala' sports with 'Royal' and 'Imperial Gala' being the most widely planted at this time. Fruit on 1-year-old wood is usually small. 'Galas' are crisp and juicy off the tree. They tend to develop cracks in the stem bowl when overmature. This variety has a short storage life.

Maturity

'Gala' apples size rapidly during the harvest season. This can be an important factor in determining financial returns of this small-fruited variety. Red skin color, firmness, soluble solids content and acidity do not relate well to internal maturity. Although red color develops differently on red clones, these clones still require selective picking. Red-striped strains are prone to reversion to less highly colored fruit.

New Zealand growers harvest 'Gala' apples

4-5 times, picking fruit on the basis of ground color. It appears that Washington growers are harvesting fruit of excellent edible quality when the ground color is changing from green to yellow (in the white). For example, in 1990 'Royal Gala' harvested with white ground color were 17.5 lbs firmness, 13.3% soluble solids and 0.376% acidity. The starch rating was 3.6 on a 1-5 scale. Starch has been used by some researchers and orchardists to time harvest. Fruit sampled for starch analysis should be of uniform ground color. In Orondo, WA, these fruit were harvested between August 29 and September 12. Fruit destined for storage should be harvested slightly on the green side. Multiple picking appears to be essential in order to have fruit of good size, color, edible quality and uniformity for storage.

Storage

'Gala' apples in storage for more than 4 months lost flavor and texture even in CA. Rapid marketing of 'Gala' will result in a product superior to that out of storage.

Fruit stored in CA tests has had similar firmness (by at least 1 pound) and higher acidity than those stored in regular storage. 'Galas' have not yet been subjected to different CA regimes. They respond well to 1% oxygen and 1% carbon dioxide at 32^{o}F.

Potential Storage Problems

Rot - Late-harvested 'Galas' appear to be more susceptible to fruit rotting fungi than those harvested at white ground color.

Firmness and Acidity Loss - Softening can occur and acidity be lost if the fruit is not place in CA directly after harvest. It is not possible to achieve good results if the CA is delayed. For example, 'Galas' harvested in early September should not be held out of CA until enough 'Goldens' are harvested in late September in order to fill a room. 'Galas' must be placed in CA immediately.

GRANNY SMITH

'Granny Smith' originated as a chance seedling near Sydney, Australia, in the 1860s. Selections of 'Granny Smith' have been widely planted in Washington-both nonspur and spur types ('Greenspur' and 'Granspur'). Virus diseases that created symptoms on fruit have been a problem in non-heat-treated nursery stock.

'Granny Smith' apples are the third largest volume apple variety shipped from Washington State, behind 'Red' and 'Golden Delicious'. Debate rages about the value of marketing solidly (emerald) green skin 'Grannies' vs. those with the "kiss of the sun." Scientists and others state that 'Grannies' allowed to develop full eating potential are superior to fruit harvested too early in order to retain green skin color. However, the worldwide 'Granny Smith' market is oriented to solidly green color 'Grannies'. This has led to the processing of good quality fruit. One year, more than 50% of the 'Granny Smith' apples grown in New Zealand were diverted simply because they were not fully green.

Judging Harvest Date

Year to year variation in fruit firmness, soluble solids content and titratable acidity indicates that these factors are more indicative of fruit quality than of maturity. New Zealand researchers have determined that the starch iodine test best determines fruit maturity. Starch clearing shows less variation between orchards and changes more uniformly over the season than either soluble solids content or flesh firmness. The New Zealand industry uses the average starch rating from 20 apples to determine harvest maturity. This agrees with work done in Australia, South Africa and

South America. They have determined that when all areas within the core line are white, a quarter of the cortex is white and the remainder is blue, the fruit is ready to harvest.

In Washington State, Max Patterson has studied 'Granny Smith' maturity and its condition after storage. He has sampled 'Granny Smith' fruit in different years and found great differences in firmness, starch, soluble solids content and titratable acidity. He suggests that the fruit not be picked until it is physiologically mature, when both edible quality and storage longevity will be optimized. Unfortunately, he is not able to suggest a field operation that can determine physiological maturity other than by measuring ethylene evolution and/or increased respiration rate. Physiological maturity on fruit from a single 'Granny Smith' orchard ranged from October 14 in 1985 and 1987 to October 28 and 1986.

In California, Gordon Mitchell determined that the starch index was the single best maturity indicator. His recommendation is to start harvest when about 30% of the cortex is white. He has observed that this occurs at about 170 days after bloom with fruit at 16 lbs firmness, 12% soluble solids content and 0.75% titratable acidity.

In South Africa extensive research has been done by A. B. Truter to determine optimum harvest date for long-term storage of 'Granny Smith'. He has developed a program similar to that used in Washington State for 'Delicious', based on noting an accelerated or decelerated rate of change of many maturity indices. He rejects the concept that maturity can be determined through specific values due to year-to-year and orchard-to-orchard variation. During different seasons the range in soluble solids content at optimum harvest was 11.4-12.5%, firmness 14-17.5 lbs, acidity 0.6-0.8% and starch 20-38% unstained cortex area.

These studies have shown that there is a picking window of 3-4.5 weeks. The Washington industry is currently considering using a certain starch clearance level as an indicator of minimum quality.

Storage Potential

Patterson has subjected 'Granny Smith' apples to regular and CA storages at different atmospheres. He has determined that Washington-grown 'Granny Smith' apples do best at oxygen levels of 0.75-1.0% with carbon dioxide at less than 0.75% at 31^{o}F. His research has shown that DPA treated fruit had less storage scald, lower ethylene levels in storage and greater firmness than nontreated fruit. His tests in regular storage have shown that 31^{o}F, compared with 34^{o} and 38^{o}F, resulted in firmer fruit with greener color and less scald, coreflush and core browning. Patterson has stored 'Granny Smith' apples in CA for a full year at low oxygen and low temperatures without negative effects.

Research from New Zealand, Australia and South Africa has suggested that rapid temperature reduction to 32^{o}F or below has led to internal browning of the fruit. Several researchers recommend CA and rapid temperature reduction to 34^{o}F for the first month and then lowering the temperature to 31-32^{o}F for the remainder of the storage period. Most researchers recommend holding the oxygen at 1-1.5% and CO_2 below 1%.

Potential Storage Problems

Sunburn, delayed sunburn - Sunburn and delayed sunburn are serious problems in 'Granny Smith' apples. Delayed sunburn appears only after the fruit is in storage, and sunburn appears while the fruit is still on the tree. Sunscald appears in storage on fruit that has been exposed to the sun while in the bin awaiting transport to the packinghouse. In New Zealand, bins are held under shade cloth before transport to the packinghouse. Various chemicals are sold that claim to reduce sunburn. Whitening agents and orchard shade cloths have been tested on trees in California without success. Modification of training and pruning is helpful in reducing sunburn. Sunscald can be reduced by holding bins of fruit under shade and covering straddle carriers to avoid direct sunlight. A DPA drench also helps retard this fruit browning.

Superficial scald - Superficial (Storage) scald is a serious problem with 'Granny Smith' apples in CA. Fruit from warmer districts is more susceptible than fruit from cooler districts at the same level of maturity. Proper harvest maturity is essential. DPA treatment is imperative with this variety if it is to be stored. DPA damage can increase on fruit with sunbleached skin. "Initial oxygen stress" used experimentally in Australia has led to reduced scald in laboratory tests with reduced amounts of DPA. When oxygen stress was initially used, coreflush and alcoholic tainting increased.

Bitter pit - 'Granny Smith' apples are very susceptible to bitter pit both on the tree and in storage. Lenticel blotch pit (a form of bitter pit) has been observed on Washington-grown fruit stored in CA. Regular season-long calcium spray programs help reduce bitter pit. Minimizing stress through proper pruning, water management and fertilizing can be very effective. Postharvest applications alone can increase fruit calcium (by less than 5%) but are not as effective as repeated orchard sprays. Application of calcium may help retain green color.

Coreflush - Fruit is susceptible to coreflush if it is picked too early or too late. Large fruit, especially from low cropping trees, is more likely to develop coreflush than moderate size fruit. Fruit from the inner shaded parts of the tree and fruit from warmer districts are more susceptible. Stepwise lowering of temperature has helped minimize coreflush. Coreflush increases when carbon dioxide levels are held above 1%. Low oxygen storage helps reduce coreflush. DPA has also been shown to help reduce coreflush.

Table 1. Maximum storage periods for new varieties picked at optimum maturity.

Variety	Regular Storage	CA storage
Gala	2-3 months	3-4 months
Jonagold	4 months	9 months
Granny Smith	6-9 months	12 months
Fuji	9 months	12 months
Braeburn	6 months	--

CONTROLLING POSTHARVEST DISEASES OF TREE FRUITS: TEMPERATURE AND THOUGHTS FOR NEW APPROACHES

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Introduction

Harvested fruit are subject to dramatic changes that result in reduced disease resistance. In general, ripe fruit are easily bruised or wounded and become more susceptible to postharvest fungal decay than mature or immature fruit. Wounds and bruises facilitate infections by fungal spores that are waiting on the fruit surface for the availability of nutrients, entry avenues, and the right environmental conditions. Temperature affects the rate of growth and spread of the decay microorganisms and, at the same time, it affects the commodity. Because germination and growth of these pathogens are prevented or slowed down by low temperatures, quick cooling of harvested commodities can prevent or slow down decay development. For instance, Rhizopus decay will be prevented if fruit are stored below 41°F, because *Rhizopus stolonifer* does not grow below 41°F. Germinated spores of this fungus are killed after about 2 days at 32°F. In contrast, brown rot or Botrytis rot will only be slowed down with this type of cold storage. Spores of the brown rot and gray mold pathogens (*Monilinia fructicola* and *Botrytis cinerea*, respectively) can survive normal fruit refrigeration temperatures, germinate and grow under prolonged storage periods, causing postharvest losses.

Cold temperature is probably the most important environmental factor in delaying product deterioration and preventing postharvest decay. Relative humidity, controlled atmosphere, and even atmospheric pressure may interact favorably with temperature to control postharvest decay. With technological advances in instrumentation and improved construction of storage facilities, there is no excuse for excessive losses due to postharvest decay. Massive losses are primarily attributed to rough handling during harvest, transit, sorting or packing, improper storage temperatures, and refrigeration failures during storage or in transit. For these reasons, knowledge of the specific characteristics of pathogens causing postharvest decay and careful control systems (provided with alarms) for refrigeration units during storage and transit are necessary.

Specific Examples of Postharvest Decay Pathogens in the Central Valley

Rhizopus and Gilbertella rots. Rhizopus decay is caused by *Rhizopus stolonifer* and Gilbertella rot by *Gilbertella persicaria*, two common soilborne fungi in stone fruit orchards and elsewhere. The spores of *Rhizopus* and *Gilbertella* move by air currents, insects, and/or with the soil dust and can reach the surface of the fruit on the trees. Once wounds are present on the fruit surface, spores of these pathogens can germinate, grow and consume the fruit tissues, quickly causing extensive decay. In storage, *Rhizopus* can move from fruit to fruit using its stolons and colonizes unwounded fruit. In contrast, *Gilbertella* does not produce stolons and cannot move from fruit to fruit. Therefore, Gilbertella rot is restricted to individual fruit while Rhizopus rot can involve a few to several fruit, depending on storage conditions. Control of *Rhizopus* and *Gilbertella* is successful by keeping the fruit below 41°F, a temperature that prevents the growth of these fungi. However, fruit are kept in the supermarket one to three days, frequently under ambient temperatures, and excessive handling of the fruit by the customers, facilitating fungal spore activation, germination, and growth which ultimately leads to fruit infection. Therefore, when wounding or bruising is inevitable, chemical postharvest treatments will help to prevent or reduce postharvest decay. Surprisingly, in a recent survey of decay organisms in a peach orchard, excluding brown rot, we found that about 75% of the isolates were *Gilbertella* and only about 25% *Rhizopus*.

Dicloran (Botran 75 WP) has been used for more than 20 years as an effective treatment to Rhizopus rot control. However, as of March of 1992, the EPA cancelled all registrations of this material, leaving the stone fruit industries with no alternative to control Rhizopus rot. Alternatives for control of Rhizopus decay could be new fungicide combinations or possibly sanitation approaches. Presently, none of the registered fungicides are effective against Gilbertella rot. With the increasing public concern about pesticides, alternatives to chemical control are needed. Our future goals are to search for possible ways to develop alternative approaches to chemical control.

Brown rot and Botrytis gray mold. Brown rot of stone fruit is caused by *Monilinia fructicola* and Botrytis gray mold by *Botrytis cinerea*. These two fungal pathogens are very closely related. However brown rot is of primary importance to the stone fruit industries since it can cause significant losses. In the last four to five years more Botrytis gray mold has been found in stone fruit than previously detected. One wonders whether the recent, five-year drought in California has something to do with such changes in the decay levels. We need new approaches and new studies for these diseases. Information on the spread of inoculum, the involvement of nitidulid beetles (dried fruit beetles) and vinegar flies, the effects of moisture and temperature on disease development both on the orchard floor and on the trees under the dry conditions of the Central Valley is missing. We can not afford losses because of a lack of such basic information about these diseases. Although low temperatures will slow down these decays, relatively long storage period allows their limited development. When fruit are then placed on the shelf in the supermarket, these pathogens are ready to flourish and cause significant losses. Cold temperatures will reduce these decays, but will not control them. A combination of cold temperature, perhaps sanitation, and a better understanding of the preharvest factors (i.e., irrigation, tree nutrition management, and other cultural practices) will be needed to control such decays.

Recently, we noticed a tendency among stone fruit growers to overfertilize their trees with nitrogen fertilizers hoping for higher yields. In cooperation with Drs. S. Johnson (horticulturist), C. Crisosto (postharvest physiologist), and K. Daane (entomologist), all located at the Kearney Agricultural Center, we initiated a study in 1990 to determine the effect of nitrogen fertilization on fruit quality and resistance to insects and brown rot of 'Flavortop' and 'Fantasia' nectarines. In summary, the results of this study clearly showed that for both varieties, fruit from trees fertilized with the higher rates of nitrogen, applied as ammonium nitrate, developed more brown rot than fruit from trees fertilized with the lower nitrogen rates. In all instances, the unfertilized control trees developed the lowest levels of brown rot and the least numbers of decay lesions on noninoculated and inoculated fruit. In addition, after inoculation in the field, blossoms from 'Fantasia' nectarine trees fertilized with the higher nitrogen levels developed more blossom blight than those from trees fertilized with the lower rates of nitrogen. Again, blossoms of unfertilized trees had the lowest amount of blight. These findings suggest that although growers may gain in yields, they will lose significant amounts of fruit due to brown rot and the overall net result cannot be as attractive as expected.

Furthermore, overfertilization with nitrogen leads to excessive leaching of nitrates that may contaminate the ground water. Therefore, with the proper management of nitrogen fertilization both brown rot disease and contamination by nitrates of ground water can be significantly reduced. We are glad to discover that growers have realized that a combination of several approaches is necessary for the effective control of stone fruit diseases.

Mucor and Penicillium decays. Mucor rot is caused by *Mucor piriformis* and Penicillium rot by *Penicillium expansum*. *M. piriformis* can easily grow relatively fast at 31-32^{o}F, and it can cause significant losses, particularly for fruit stored for long periods of time such as pears and apples. Although cold temperature can affect the rate and development of decay, both Mucor rot and blue mold can cause significant damage. In the case of Mucor rot, because the pathogen's spores can germinate and grow at 31 to 32°F, losses can be detrimental, this is particularly true in 'Anjou' pears. Occasionally, this fungal pathogen can cause losses in peaches, nectarines (as happened in 1977) and plums and 'Fuji' apples (in 1990). Recently, losses from *Mucor piriformis* were recorded in raspberries grown in Salinas. Because *Mucor* is a soilborne fungus, contamination of fruit with soil from the orchard ground can explain the significant amounts of decay. In a study done in cooperation with Oregon State University, we showed that cleanliness of the harvest bins significantly affects the levels of Mucor decay. In addition, we found that fruit from orchards with high levels of spore inoculum in the soil developed higher levels of Mucor decay in storage. Therefore, at least for some of the pathogens, we know that the spore inoculum in the orchard correlates directly with levels of decay in storage. In addition, because the maximum temperature for growth of this fungus is relatively low (81°F) in comparison with that of the brown rot and Rhizopus rot pathogens (90-95°F), high temperature has been used experimentally to reduce decay. For instance, in a study we showed that dipping 'Anjou' pears at 117°F (47°C) for 30 minutes prevented Mucor rot. This treatment did not result in any phytotoxic symptoms on the fruit. Although this approach has been used commercially for tropical fruit, it has not yet been tried commercially as a postharvest treatment of pears. However, because of public concern about the use of various fungicides, all nonchemical approaches should be seriously considered.

Approaches that seemed impractical in the past may become practical in the near future with the support of the advancement of science and technology.

We plan to initiate extensive studies on brown rot, Rhizopus, and Gilbertella rots, the three commonly found postharvest diseases of stone fruit in the Central Valley. Extensive research on *M. piriformis* helped the pear growers in Oregon to reduce Mucor decay significantly. Currently, growers follow recommendations based on research findings and we believe such information on stone fruit postharvest pathogens is more relevant now and should be obtained without any delay.

Penicillium rot is not very common in stone fruit but it is the number one decay pathogen of citrus in storage. Penicillium rot may become a significant problem in stored apples. Although cold temperatures will slow down the progress of decay, they can not prevent its development. Under prolonged storage at near 32°F, the pathogen can grow, sporulate, decay, and contaminate additional fruit in storage. Wounding or bruising of fruit is necessary for *Penicillium* to cause infection. Again, it becomes obvious how careful all fruit should be handled. In addition, sanitation could be an approach to control this disease and needs further investigation. In conclusion, support for additional research to develop new approaches for controlling these postharvest organisms is necessary.

CONDITIONING GRANNY SMITH APPLES FOR MARKET

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There is normally a good market for Granny Smith apples at the start of the commercial harvest season. Consumers can often turn away from the fruit, however, because of their high acidity and apparent low sugars. Early tests indicated the possibility of using controlled ripening, or "conditioning", to convert starch to sugars and slightly reduce acid content.

Fruit from 3 locations were conditioned by holding for 6 days at 25°C (77°F) with 10 ppm ethylene to evaluate possible effects on edibility, physical and chemical changes, and storage performance. Physical and chemical changes were also monitored on conditioned fruit from a number of locations. While conditioning is not needed if fruit are to be stored, tests were continued for 4 months to determine the longer term effect of conditioning on storage life.

The results show that conditioning cannot be used to improve immature fruit; however, mature fruit from early to mid-commercial harvest showed a substantial improvement in edibility. By late commercial harvest all samples were judged to be highly edible, and there was little gain from the conditioning treatment.

Conditioning had very little effect on flesh firmness but did advance soluble solids content and speed disappearance of starch and acidity. After 4 months' storage there was less storage scald in conditioned fruit (especially late harvest), very little difference in flesh firmness, color and core flesh. Because no bitter pit developed in fruit from the 3 locations, the effect of conditioning on this disorder could not be evaluated.

These results indicate that conditioning can improve the edibility of freshly harvested Granny Smith apples that are harvested during early to mid-commercial season, and marketed without storage. The treatment does little to improve the taste acceptance of earlier-harvested (immature) fruit. By late harvest season there is little benefit in improved acceptance from conditioning because all fruit have fairly high acceptance. There was an apparent reduction in the development of storage scald associated with the conditioning treatment, but the effect of the treatment on development of bitter pit remains unknown. Thus, conditioning Granny Smith apples for 6 days at 77°F (25°C) with ethylene may be a useful treatment to improve edibility of freshly harvested fruit.

GRANNY SMITH APPLE MATURITY STUDIES

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A study is underway in 10 California counties with the help of farm advisors. This report summarizes the results of the 1986 study. Fruit were sampled at 10-day intervals from 140 to 200 days from full bloom, and monitored at harvest and monthly to four months' storage at 33°F (0.5°C). A range of maturity measures and performance measures were taken, and the usefulness of individual and combination maturity measures compared. Fruit size increase during harvest was also monitored.

Many scores assigned to both maturity measures and storage performance are subjective. Further, a storage performance index for fruit from each orchard was subjectively selected by balancing changes in bitter pit, storage scald, core flush, rate of flesh softening and taste scores; and this index was used to compare harvest maturity measures from all locations.

The single harvest index that best correlated with storage performance was starch pattern as measured by the starch/iodine test. A minimum 2.5 score (on the 0-6 scale) indicated good storage performance, with a correlation among the 10 orchards of 0.89 (1.00 = perfect correlation). A 2.5 starch index would be achieved when about half of the fruits in a sample graded 2 (core area white, cortex blue) and half graded 3 (core area white, 1/4 of cortex white, balance blue).

A slightly better correlation was achieved by combining starch and seed color (correlation

= 0.94), but it is questionable if this slight improvement is worth the extra effort. Minimum seed color for good storage performance was 3.5 (on a 0-5 scale). A 3.5 seed color score would be when seeds were between 1/2 and 3/4 brown.

Size increases were consistent throughout the harvest period. Fruit gained about 1/2 size per 10 days on the tree. Yield increases when the fruit were near normal commercial harvest time approximated 0.5-0.6% per day.

RECENT DEVELOPMENTS IN THE POSTHARVEST STORAGE OF CALIFORNIA CITRUS

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Regulatory issues dealing with agricultural chemicals are the major postharvest concern of the California citrus industry in 1992. Re-registration costs can eliminate long-used agricultural chemicals although no issues of environmental or food safety exist. Two compounds registered and widely used by the California citrus industry, sodium ortho-phenyl phenate (SOPP) and the isopropyl ester of 2,4-D, may be lost because the economic burden to the manufacturers of re-registration with the EPA is too high.

SOPP reduces postharvest Penicillium green and blue molds and partially reduces Geotrichum sour rot. In order to raise the estimated $3 million needed for the residue and toxicology studies required for re-registration of SOPP, the California Citrus Quality Council has spear-headed actions to raise funds from non-chemical industry sources. A referendum within the citrus industry to increase the box assessment to contribute to a re-registration fund will occur in the fall of 1992. The California-Arizona Citrus League will provide ca. $800,000 in seed money for the first year's work, contingent on repayment from the increased assessment.

Applications of 2,4-D before harvest help prolong retention of fruit on trees, while applications after harvest retard button senescence and reduce Alternaria stem end decay. As with SOPP, the chemical industry will not support re-registration of this form of 2,4-D, although they do seek to re-register herbicide registrations of 2,4-D. In response to these developments, the citrus industry has affirmed its continued support of research into alternative treatments, and seeks to accelerate this work.

Methyl bromide, little used by the citrus industry today, would be widely employed for the medfly and other fruit flies if quarantine requirements demanded it. Recently, the California Department of Pesticide Regulation has requested atmosphere monitoring data to determine if significant human exposure occurs as a consequence of fumigation. In response, the citrus industry has joined with other fresh fruit groups to monitor methyl bromide during chamber, tarpaulin, and truck van fumigations. Methyl bromide and cold treatment are the only approved quarantine treatments for fruit flies.

Increased fungicide resistance exhibited by citrus postharvest pathogens in California (thoroughly documented by UC Riverside workers) and an unfavorable regulatory climate toward fungicides has made the development of new decay management strategies a high priority. Approaches by the USDA-ARS in Fresno include the use of microbial biological control agents to control green mold, either alone or combined with other sanitizing agents. Strains of the bacterium *Pseudomonas cepacia* shows curative action in laboratory tests. Brief immersion in warm sulfur dioxide solutions, followed by two fresh water rinses, controlled green mold on lemons. Control was obtained even if the process was applied 48 hours after inoculation. Work at UC Riverside showed good control of green mold by a postharvest curing treatment of warm temperature and high humidity. This treatment enhances natural defenses of the fruit, recently described as wound gums and other antifungal compounds.

IMPROVED SULFUR DIOXIDE FUMIGATION OF TABLE GRAPES

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Table grapes can be stored for three months or more if held near 31^{o}F and periodically fumigated with sulfur dioxide. Since the 1920's fumigation with gaseous sulfur dioxide has been a common practice. The amount of gas used was high enough to control *Botrytis*, but low enough to prevent bleaching the berries. In 1987, sulfur dioxide was reclassified as a hazardous pesticide and the EPA placed an additional requirement that residue levels of this chemical in stored and shipped table grapes must be less than 10 ppm. A research project was begun the next season to develop fumigation procedures that would control decay and still keep fumigant residues less than 10 ppm. Project cooperators were Don Luvisi, Kern Co. Cooperative Extension; Harry Shorey, UC Berkeley Department of Entomology; Joe Smilanick, USDA-ARS Horticultural Crops Laboratory, Fresno; Barry Gump, CSU Fresno Chemistry Department; and Jim Thompson and Jerry Knutson, UC Davis Biological and Agricultural Engineering Department.

Extensive laboratory research showed that the amount of sulfur dioxide gas needed to kill *Botrytis* spores or to inactivate exposed mycelium is dependent on the concentration and the length of time the fungus is exposed to the fumigant. A cumulative concentration, calculated as the produced of concentration and time, called "CT product", describes the sulfur dioxide exposure needed to kill the decay organism. A CT of 100 ppm-hours is required to kill *Botrytis* at 32^{o}F. This can be obtained as an average concentration of 100 ppm for 1 hour, or 200 ppm for 1/2 hour, or 50 ppm for 2 hours, or an equivalent combination of concentration and time.

Before the regulation changes, most cold storages were fumigated with enough sulfur dioxide to produce a 2500 ppm concentration, based on the empty room volume, for 20 to 30 minutes and then the fumigant was vented to the atmosphere or scrubbed from the room. In practice the concentration rarely got to 2500 ppm and the sulfur dioxide concentration dropped rather quickly as it was absorbed by packaging material and fruit. Still, the total CT for a conventionally fumigated room was 20 to 40 times the required 100 ppm-hrs, far higher than needed. However, we found that, in storage room fumigation, sulfur dioxide often does not penetrate well to the center boxes in a pallet and high fumigant levels are needed to overcome the poor penetration.

We recommend that the first fumigation be done in conjunction with forced air cooling. The forced air flow through the boxes causes the sulfur dioxide to have good access even to the center boxes on a pallet. In most all combinations of box and pack, this system produces over 80% penetration, measured as per cent of the room air CT product. Unfortunately, we have not been able to develop a method of forced air fumigation that will work in cold storage fumigations and these may be subjected to poor and variable sulfur dioxide penetration.

The amount of sulfur dioxide that penetrates a box in cold storage fumigation is dependent on a number of factors: 1) box design, 2) packing method, 3) air speed past the box, 4) position of pallet in a storage room, 5) position of box on a pallet, 6) cold room construction materials, 7) humidity of the cold room. In some poorly vented boxes, the penetration of sulfur dioxide into the package can be less than 10%. Differences in penetration can cause some boxes in a cold room to receive excessive exposure to sulfur dioxide and risk exceeding residue tolerances, other boxes may not receive adequate fumigant exposure and may be subject to decay. Variation in penetration can be minimized by: 1) insuring that air speed past pallets is at least 140 feet per minute during the first one or two hours of fumigation, 2) segregating boxes with dissimilar packs into different rooms, 3) as inventory decreases, consolidating fruit into fewest possible rooms to minimize the number of open pallet lanes.

We developed a new method of fumigation we call the "total utilization" system. It differs from the traditional system in that there is no excess fumigant at the end of the fumigation operation. The fumigation process is extended to six to 12 hours so that nearly all of the sulfur dioxide is absorbed by fruit, packaging materials, and room surfaces. At the end of fumigation, sulfur dioxide concentration in the room air is usually less than 2-5 ppm and no venting or scrubbing is needed. Total utilization often uses at least half as much sulfur dioxide as the traditional method and improves uniformity of fumigant penetration. It can be used with forced air cooling for initial fumigation and in cold storage for subsequent treatments.

All cold storage rooms should be calibrated to determine amount of sulfur dioxide to use, remembering that center boxes on a pallet have lower sulfur dioxide concentration than corner boxes and pallets closest to sulfur dioxide inlet have lower fumigant concentrations compared with those farthest away. We found that inexpensive sulfur dioxide dosimeters, originally designed for human safety monitoring, work well for measuring sulfur dioxide CT product inside packed grape boxes. The glass dosimeter tubes are placed in the center of boxes, usually boxes in the center of test pallets. After fumigation the tubes are removed and directly record the ppm-hr exposure to sulfur dioxide. This allows the operator to adjust the amount of fumigant applied to insure that most boxes are adequately protected from decay but not exposed to fumigant levels that might cause excessive residues.

More details of this work are contained in the newly released, 20 page leaflet titled: Sulfur Dioxide Fumigation of Table Grapes, published by University of California Division of Agriculture and Natural Resources. Copies can be purchased from county extension offices or ordered from: Publications, University of California Agriculture and Natural Resources, 6701 San Pablo Ave., Oakland, CA 94608-1239 (Leaflet No. 1932).