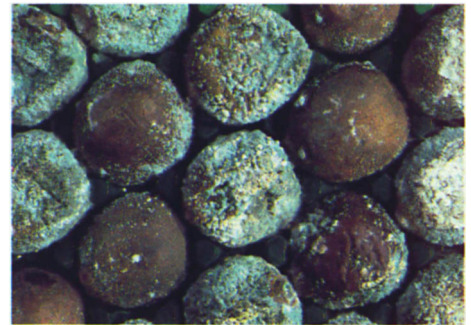


Careful handling and proper storage are crucial to avoid postharvest losses



Wetness from exuding juice often accompanies phomopsis rot in kiwifruit.

Below: *Penicillium* blue mold rot occasionally affects injured fruit.



Minimizing postharvest diseases of kiwifruit

Noel F. Sommer □ Robert J. Fortlage □ Donald C. Edwards

Kiwifruit production is one of the nation's newest and fastest-developing agricultural industries, most of which is located in the California Central Valley. California production has developed as a consequence of the phenomenal success earlier scored by New Zealand pioneers who developed the first kiwifruit industry outside of the fruit's native home, China.

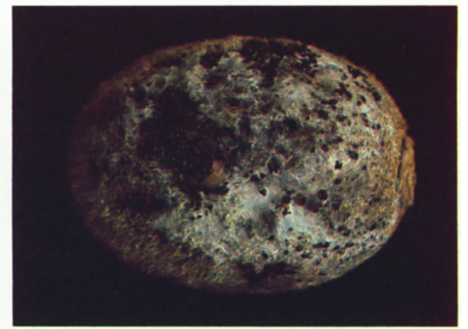
As with most new industries, the best methods for handling, storage, and transportation of kiwifruits were largely unknown. Ultimately, handling methods are dictated, in part, by postharvest diseases or the threat of postharvest diseases. Commonly, when a fruit-growing industry develops in a new area, the commodity may initially be relatively free of disease during storage and transport. As acreages increase, however, postharvest diseases appear and interfere with the orderly marketing of the commodity. Postharvest diseases thus far observed in kiwifruit are discussed so that growers and handlers may become familiar with the diseases,

their characteristics, and possible measures for avoidance or control.

Botrytis gray mold rot

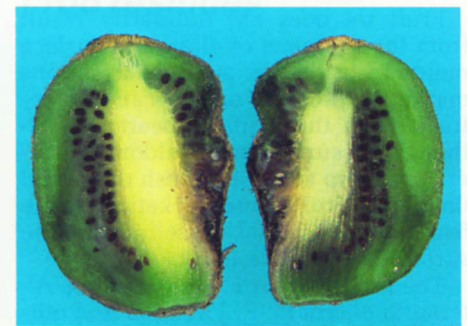
The disease posing the greatest threat in kiwifruit marketing is gray mold rot caused by the fungus *Botrytis cinerea* Pers. ex Fr., well known in California for its damage to grapes. In California kiwifruits, the decay has been limited to fruit in storage or marketing channels. The first indication of the onset of fruit rot is usually the appearance of tiny tufts of white mycelium growing through the fruit skin. The fruit flesh in the fungus-invaded area is very soft, and in extreme cases may be nearly liquefied. The lesion usually develops at the point where infection initially occurs.

Botrytis cinerea gains entrance into various fruit hosts in several ways, most commonly the following: (1) Wounds may be inflicted on the fruit during harvesting and handling; even minute injuries suffice if the fruit skin is broken and a spore becomes lodged in the



Above, at left: Typical stem-end rot caused by *Botrytis*, the most serious kiwifruit storage disease. Center: "Nest" of botrytis rot in packed fruit stored under high humidity. Right: Sclerotia developing on fruit blacken the surface.

Below, left: *Alternaria* surface mold infects flower parts, such as these adhering styles. Center: *Alternaria* mold also may develop on sepals as they wither during storage. Right: *Alternaria* associated with severe sunburn produces hard, dry rot.



wound. (2) Styles, stamens, and petals may be colonized by various fungi near the end of bloom; those colonized by *B. cinerea* may serve as inoculum. (3) Tissues at the fruit stem may be contaminated. (4) The fungus may directly penetrate the fruit skin, a process usually requiring a period of two or three days of rainfall or extremely high humidity. In kiwifruit it is uncertain which modes of infection are the most important.

When fruit is stored under high humidity, considerable aerial mycelium grows out from the surface of infected fruits. The mycelium is capable of growing an inch or more from rotting fruits to contact nearby sound fruits, penetrating them and causing them to rot in turn. A "nest" of rotting fruit is the result. Such mycelial contact and nesting is the usual means by which the disease spreads in storage.

Surface mycelium may occasionally change from white to a pronounced gray color as a result of spore production. Sometimes the formation of firm, compact sclerotia causes the surface to be-

come black. Sclerotia permit the fungus to overwinter in cold climates but they seem to play no important role in the storage rot of California kiwifruits.

Botrytis rot appears to be closely associated with fruit condition. Unlike the same fungus in grapes, kiwifruits in the field appear to be unaffected by the fungus and may be highly resistant. Based on several years of observation and storage tests, we believe that normal, unstressed fruits do not become susceptible to botrytis rot until they are nearly ripe, as indicated by fruit softening.

Kiwifruits appear unique among deciduous fruits in their ability to ripen rapidly in 32° F storage. Inadvertent exposure of the fruit to ethylene from the exhausts of cars, trucks, forklifts, and the like, or from other fruits such as apples, may trigger ripening. Badly bruised or rotting fruit in the vicinity are other sources of the ethylene that may trigger ripening. Delays in removing field heat or use of storage temperatures above 32° F also tend to limit the

fruits' physiological life.

In recent tests we compared the storage behavior of fruits from five widely separated Central Valley plots. Plot 1 was in the northern part, and 2 and 3 were in the southern part of the San Joaquin Valley. Plots 4 and 5 were in the Sacramento Valley. Adhering floral parts, mostly styles, were collected from 100 fruits just before blossoming, in midseason, and just before harvest. The presence of *B. cinerea*, determined by common laboratory culture techniques, varied from 0 to 15 percent in samples of usually 100 fruits (table 1). By October, just before harvest, only one location had not shown the presence of *B. cinerea* in adhering floral parts.

Two hundred fruits from each of the same plots were harvested and handled carefully to prevent injury and cooled to 32° F within 10 hours; ethylene exposure was rigorously prevented. After six months of storage, fruits from three of the five plots still showed little rot. At that point all were warmed to 45° F in the presence of 2.6 ppm ethylene and

held two weeks for further disease development.

Under the same storage conditions fruit from various locations differed in rot development (table 2). Fruits from plots 1 and 4 had the highest level of blossom infection and also had the highest fruit rot, suggesting that blossom sprays might be beneficial. Very little rot occurred where the average penetrometer reading (U.C. pressure tester with a 1/16-inch tip) was above 2 pounds. We suspect that *Botrytis cinerea* is primarily active at fruit ripenesses represented by pressure tests of about 1.5 pounds or less.

Alternaria surface mold

Fruit rot does not ordinarily result from the presence of *alternaria* surface mold. Instead, the mold is a serious marketing problem only because it detracts from the fruits' appearance. Although the surface mold seldom or never appears to attack the flesh of normal unstressed fruit, some marketing people fear that the fungal mycelium on the surface is a prelude to rot.

The problem starts at blossoming. *Alternaria alternata* (Fr.) Keissler and other fungi invade petals, styles, and stamens during and after full bloom. Typically, the fungi thoroughly colonize these floral parts but become inactive as the parts dry. By harvest, commonly only the styles are still firmly attached to the fruit. Fragments of petals and especially stamens may be found along with other debris entangled in the plant hairs (trichomes) covering the fruit surface.

Once in storage, the high humidity required to prevent fruit shrivel permits the fungi in the styles, stamens, and debris to become active. Of the various fungi present, usually *Alternaria* spp. predominate among those capable of growing at the 32° F storage temperature recommended for kiwifruits. If sepals have not been removed by brushing, often they also become invaded by *Alternaria* spp. as they wither in storage.

Brushing fruits to completely remove styles and sepals would eliminate the

TABLE 2. Botrytis rot and flesh firmness (in parentheses) of kiwifruits in storage

Plot	Accumulated decayed fruit (and flesh firmness) after storage*							
	4 mo		5 mo		6 mo		6 mo + 2 wk	
	%	lb	%	lb	%	lb	%	lb
1	0	(4.2)	0	(2.4)	2.5	8.5	(0.6)	
2	0	(6.7)	0	(3.7)	0	1.0	(1.0)	
3	0.5	(3.4)	0.5	(3.3)	0.5	2.0	(1.0)	
4	1.0	(2.3)	1.0	(1.8)	22	38.5	(0.6)	
5	0	(7.9)	0	(7.2)	0	0.5	(1.0)	

*Fruits with varying levels of blossom infection were handled to avoid injury or ethylene exposure. Field heat was removed within 10 hours and fruits were stored in air at 32° F for six months, after which they were held for two weeks at 45° F in presence of 6 ppm ethylene.

alternaria surface mold problem, but it is uncertain how thoroughly this brushing can be done.

Alternaria rot

Fruits that have been sunburned in the field are often found to be colonized by *Alternaria* spp., producing a hard, dry rot. Although the same fungi are involved with *alternaria* rot as with *alternaria* surface mold, there appears to be no other connection. Discarding sunburned fruit by sorting appears to eliminate *alternaria* rot.

Other rots

Phomopsis stem-end rot, caused by *Diaporthe actinidiae* Som. & Ber., was observed in New Zealand kiwifruits at retail during the late 1960s and early 1970s and first occurred in California-grown fruit during 1981-82. Typically, the disease occurred at the stem end of the fruit, where wetness was often observed from exuded fruit juice. A secondary invasion of yeast sometimes resulted in frothing of exuding juice and attracted vinegar flies. Fruit flesh in the lesion area became very soft.

Blue mold [*Penicillium expansum* (Lk.) Thom] has occasionally rotted injured fruit. At least once during the 1981-82 storage season, the disease severely affected a large proportion of fruits in some containers. It is likely that infections mostly result from contamination of fruit wounds, as is the case with other stored deciduous species.

Disease control

Fruit ripening precedes the appearance of the major fungal problems of stored kiwifruits, with the one exception of *alternaria* surface mold. As a consequence, emphasis should be placed on slowing ripening during storage. Unfortunately, there is no single quick or easy way to accomplish that objective. Instead, an awareness of good handling practices and careful supervision of all postharvest operations is required.

Removal of field heat should follow harvest within a few hours. Delays in cooling harvested fruits can be expected to significantly hasten ripening in stor-

age. Fruit should be stored at 32° F; a higher temperature hastens ripening, and a lower temperature increases the hazard of freezing. It should be understood that if fruits are removed for examination and warming occurs, considerable time may elapse before they recool to near storage temperatures.

Exposure to ethylene gas must be avoided to prevent rapid fruit softening during storage. Since exhausts of forklift trucks with internal combustion engines are common sources of ethylene only electric forklifts should be used in kiwifruit handling.

Use of controlled atmospheres (CA) of about 2.5 percent oxygen and 5 percent carbon dioxide have slowed ripening considerably in tests when CA storage followed good handling practices.

Penetrometer measurements are a true indication of fruit flesh softness when a portion of the skin is removed at the point of penetration. "Finger tests" to assess firmness are notoriously misleading. Periodic penetrometer tests to determine the rate at which the stored fruit is softening make it possible to estimate the time available for marketing. Rapidly softening fruit could be marketed before *botrytis* rot is likely to be excessive.

Alternaria surface mold is essentially eliminated if styles and sepals are removed before storage by brushing.

A postharvest fungicidal treatment consisting of orthophenylphenate (OPP) for *alternaria* surface mold and DCNA (Botran) for *botrytis* rot is available in a wax formulation. Applications after harvest should reduce mold and rot from infections originating in handling wounds or from contact with adjacent rotting fruits. Rot originating from infections that occur in the field and remain quiescent until fruits soften in storage probably would not be controlled. The fungicide-wax treatment currently cannot be used for fruits marketed in some foreign countries.

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TABLE 1. Kiwifruits with *Botrytis cinerea*-colonized floral parts (mostly styles)

Plot*	Fruit with <i>Botrytis</i> †		
	Jun	Aug-Sep	Oct
	%	%	%
1	15	4	3
2	0	0	0
3	0	0	0
4	2	4	5
5	---	2	1

*Plot 1 was in northern San Joaquin Valley; 2 and 3 in southern San Joaquin Valley; 4 and 5 in Sacramento Valley. †Shown as percentage of 100-fruit samples.